PB89-166631

Advanced Utility Simulation Model
Program Documentation
State Level Model (Version 1.0)

Illinois Univ. at Urbana-Champaign

Prepared for

Environmental Protection Agency
Research Triangle Park, NC

Jan 89

U.S. Department of Commerce
National Technical Information Service
NTIS

PB89-166631

EPA/600/8-88/071b
January 1989

ADVANCED UTILITY SIMULATION MODEL
PROGRAM DOCUMENTATION
STATE LEVEL MODEL (VERSION 1.0)

by

James J. Stukel (Group Leader)
Universities Research Group on Energy
University of Illinois at Urbana-Champaign

EPA Cooperative Agreement CR808514

EPA Project Officer

Larry G. Jones
Air and Energy Engineering Research Laboratory
Research Triangle Park, North Carolina 27711

AIR AND ENERGY ENGINEERING RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NC 27711

REPRODUCED BY
U.S. DEPARTMENT OF COMMERCE
NATIONAL TECHNICAL INFORMATION SERVICE
SPRINGFIELD, VA. 22161

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA/600/8-88/071b

2.

3. RECIPIENT'S ACCESSION NO. PB89 166631/AS

4. TITLE AND SUBTITLE Advanced Utility Simulation Model, Program Documentation, State Level Model (Version 1.0)

5. REPORT DATE January 1989

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S) James J. Stukel (Group Leader)

8. PERFORMING ORGANIZATION REPORT NO.

9. PERFORMING ORGANIZATION NAME AND ADDRESS
University of Illinois at Urbana-Champaign
College of Engineering
901 South Mathews Avenue
Urbana, Illinois 61801

10. PROGRAM ELEMENT NO.

11. CONTRACT/GRANT NO. CR808514

12. SPONSORING AGENCY NAME AND ADDRESS
EPA, Office of Research and Development
Air and Energy Engineering Research Laboratory
Research Triangle Park, NC 27711

13. TYPE OF REPORT AND PERIOD COVERED Final; 9/80 - 8/85

14. SPONSORING AGENCY CODE **EPA/600/13**

15. SUPPLEMENTARY NOTES AEERL project officer is Larry G. Jones, Mail Drop 62, 919/541-7716.

16. ABSTRACT

The report is one of 11 in a series describing the initial development of the Advanced Utility Simulation Model (AUSM) by the Universities Research Group on Energy (URGE) and its continued development by the Science Applications International Corporation (SAIC) research team. The AUSM is one of four stationary source emission and control cost forecasting models developed by EPA for the National Acid Precipitation Assessment Program (NAPAP). The AUSM projects air pollution emissions (SO2 and NOx), generating technology types and costs of operation, and combinations of fuels and emission control technologies to simultaneously meet electric demand and emission constraints on a least cost basis for each year through 2010. Thirteen electric demand regions are simulated, and output is provided for each of the 48 states. The initial version of AUSM, designated Version 1.0, was delivered by URGE in November 1984 and August 1985. Further development of the AUSM by SAIC between 1985 and 1988 has resulted in the development of Versions 2.0 and 3.0. Reports describing these revisions by SAIC to the initial Version 1.0 of AUSM are also part of this series.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS		b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group	
Pollution	Sulfur Dioxide	Pollution Control	13B	07B
Utilities	Nitrogen Oxides	Stationary Sources		
Emission	Fuels		14G	21D
Cost Analysis	Electrical Power Demand		14A	
Simulation				20C
Forecasting	Mathematical Models			12A

18. DISTRIBUTION STATEMENT **Release to Public**

19. SECURITY CLASS *(This Report)* **Unclassified**

20. SECURITY CLASS *(This page)* **Unclassified**

21. NO. OF PAGES 615

22. PRICE

EPA Form 2220-1 (9-73)

NOTICE

THIS DOCUMENT HAS BEEN REPRODUCED FROM THE BEST COPY FURNISHED US BY THE SPONSORING AGENCY. ALTHOUGH IT IS RECOGNIZED THAT CERTAIN PORTIONS ARE ILLEGIBLE, IT IS BEING RELEASED IN THE INTEREST OF MAKING AVAILABLE AS MUCH INFORMATION AS POSSIBLE.

NOTICE

This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

ABSTRACT

The report is one of 11 in a series describing the initial development of the Advanced Utility Simulation Model (AUSM) by the Universities Research Group on Energy (URGE) and its continued development by the Science Applications International Corporation (SAIC) research team. The AUSM is one of four stationary source emission and control cost forecasting models developed by EPA for the National Acid Precipitation Assessment Program (NAPAP). The AUSM projects air pollution emissions (SO_2 and NO_x), generating technology types and costs of operation, and combinations of fuels and emission control technologies to simultaneously meet electricity demand and emission constraints on a least cost basis for each year through 2010. Thirteen electricity demand regions are simulated, and output is provided for each of the 48 contiguous states. The initial version of AUSM, designated Version 1.0, was delivered by URGE in November 1984 and August 1985. Further development of the AUSM by SAIC between 1985 and 1988 has resulted in the development of Versions 2.0 and 3.0. Reports describing these revisions by SAIC to the initial Version 1.0 of AUSM are also part of this series.

CONTENTS

Chapter ... Page

Abstract ... iii

Figures ... viii

Tables ... x

Abbreviations ... xiii

Acknowledgements ... xiv

A. Introduction ... A.1
  A.1 Background ... A.1
  A.2 Scope of Documentation ... A.2
  A.3 System Design and Operation ... A.2
  References ... A.9

B. Preprocessors

  B1 The Coal Supply Module ... B1.1
    B1.1 Overview ... B1.1
    B1.2 Distribution of Reserves (Program QUANT) ... B1.3
    B1.3 Model Mine Costs (Program MNCOST) ... B1.37
    B1.4 Minemouth Cost (Program RGCOST) ... B1.41
    B1.5 Delivered Prices (Program LEASTC) ... B1.80
    B1.6 Least Cost Output Reformatting (Program MAKE6) ... B1.126
    References ... B1.139

  B2 The MPMS Module ... B2.1
    B2.1 Overview ... B2.1
    B2.2 Central Algorithms and Basic Assumptions ... B2.2
    B2.3 Data Handling ... B2.3
    B2.4 Program and Subroutine Summaries ... B2.4
    B2.5 Variable Definitions ... B2.12
    References ... B2.16

C. The Model

  C3 The Control Program ... C3.1
    C3.1 Overview ... C3.1
    C3.2 Control Program Tasks ... C3.1
    C3.3 Procedures ... C3.24
    C3.4 Flow Diagrams ... C3.47
    C3.5 Variable Information ... C3.61
    References ... C3.70

C4 The Demand Module C4.1
C4.1 Overview C4.1
C4.2 Central Algorithms and Basic Assumptions C4.4
C4.3 Data Handling C4.12
C4.4 Subprogram Descriptions C4.14
C4.5 Subprogram Flowcharts C4.18
C4.6 Demand Module Variables C4.18
References C4.48

C5 The Capacity Planning Module C5.1
C5.1 Overview C5.1
C5.2 Central Algorithms and Basic Assumptions C5.2
C5.3 Data Handling C5.9
C5.4 Subroutine Summaries C5.11
C5.5 Flowcharts of Principal Subroutines C5.23
C5.6 Variable Definitions C5.36
References C5.36

C6 The Pollution Control Module C6.1
C6.1 Overview C6.1
C6.2 Operation C6.2
C6.3 Data Handling C6.16
C6.4 Subroutine Descriptions C6.23
C6.5 Flowcharts of Principal Subroutines C6.47
C6.6 Variable Definitions C6.47

Appendix C6a Simulating Market Management Systems Using the Advanced Utility Simulation Model C6a.1
C6a.1 Introduction C6a.1
C6a.2 Logic Flow for Section 3 of COMPLY: Scan of Unit Inventory C6a.1
C6a.3 Subprogram Summaries C6a.4
C6a.4 Variable Definitions C6a.11

C7 The Dispatching Module C7.1
C7.1 Overview C7.1
C7.2 Central Algorithms and Basic Assumptions C7.1
C7.3 Data Handling C7.4
C7.4 Subprogram Descriptions C7.4
C7.5 Flowcharts C7.7
C7.6 Dictionary of Variables C7.7
References C7.26

C8 The Financial Module C8.1
C8.1 Overview C8.1
C8.2 Module Operation C8.2
C8.3 Data Handling C8.23
C8.4 Subprogram Descriptions C8.25
C8.5 Financial Module Variables C8.28

Preceding page blank

C8.6 Subprogram Flowcharts C8.28
References C8.60

C9 The Report Writer C9.1
C9.1 Overview C9.1
C9.2 AUSMR: The Report Writing Program C9.6

D Utility Programs

D.10 The Scenario Selector D10.1
D10.1 Introduction D10.1
D10.2 Subroutine Summaries D10.2
D10.3 Variables D10.19
References D10.19

D.11 The Report Selector D11.1
D11.1 Overview D11.1
D11.2 Subprogram Summaries D11.3

FIGURES

Figure **Page**

Figure A.1 Overview of AUSM Execution A.8
Figure A.2 AUSM Logic Flow A.10

Figure B1.1 Minemouth Cost Preprocessor Programs and Data Files B1.2
Figure B1.2 Program QUANT Flowchart B1.10
Figure B1.3 Program MNCOST Flowchart B1.44
Figure B1.4 Program RGCOST Flowchart B1.49
Figure B1.5 Logical Flow of LEASTC B1.82
Figure B1.6 Heuristic for Determining Permissible Preparation Paths Under Mandatory Washing Scenario B1.86
Figure B1.7 LEASTC File I/O B1.87
Figure B1.8 Flowchart of LEASTC Main Program B1.103
Figure B1.9 Subroutine COSTRD Flowchart B1.109
Figure B1.10 Subroutine ELIM Flowchart B1.112
Figure B1.11 Subroutine OFFER Flowchart B1.113
Figure B1.12 Program UPCHAR Flowchart B1.115
Figure B1.13 Program MAKE6 Flowchart B1.128

Figure C3.1 AUSM Logic Flow C3.2
Figure C3.2 Construction of Data Group 70 Binary File From E5 File C3.4
Figure C3.3 Hypothetical Construction Schedule at the Beginning of 1983 .... C3.7
Figure C3.4 Hypothetical Construction Schedule at the End of 1983 .... C3.8
Figure C3.5 BEGNYR Flow Diagram C3.48
Figure C3.6 ENDYR Flow Diagram C3.51
Figure C3.7 G23ACC and RTROAC Flow Diagram (Construction Schedules Accessing) C3.55
Figure C3.8 G70ACC Flow Diagram C3.57
Figure C3.9 UNSCNR Flow Diagram C3.59

Figure C4.1 Schematic Representation of the Demand Module C4.2
Figure C4.2 Data Flow of the Demand Module C4.3
Figure C4.3 Subroutine DEMAND Flowchart C4.19
Figure C4.4 Subroutine GETQ Flowchart C4.26
Figure C4.5 Schematic Representation of Exogenous Demand and Recalibration of Demand . C4.27

Figure C5.1 Summary of Capacity Planning Control Flow C5.3
Figure C5.2 Summary of Capacity Planning Inputs and Outputs C5.4
Figure C5.3 Subroutine ADVANC C5.24
Figure C5.4 Subroutine ARANK C5.26
Figure C5.5 Subroutine DEFER C5.29
Figure C5.6 Subroutine DRANK C5.30
Figure C5.7 Subroutine PLAN C5.31
Figure C5.8 Subroutine UPSCHD C5.33
Figure C5.9 Subroutine POLPEN C5.35

Figure C6.1 COMPLY Flowchart C6.3
Figure C6.2 Control Technology Data Flow C6.8
Figure C6.3 IMPACT Flowchart C6.9
Figure C6.4 IMPACT Data Flow C6.11
Figure C6.5 Calling Sequence for Major Subprograms - COMPLY C6.24
Figure C6.6 Calling Sequence for Major Subprograms - IMPACT C6.25
Figure C6.7 ALTCOL Flowchart C6.48
Figure C6.8 ALTER Flowchart C6.50
Figure C6.9 BLEND Flowchart C6.52
Figure C6.10 CNTROL Flowchart C6.53
Figure C6.11 DISPSL Flowchart C6.55
Figure C6.12 EMITRT Flowchart C6.56
Figure C6.13 FGDCST Flowchart C6.57
Figure C6.14 NOXBLD Flowchart C6.58
Figure C6.15 TSPBLD Flowchart C6.59
Figure C6.16 PCTLGO Flowchart C6.60
Figure C6.17 TSPCST Flowchart C6.61

Figure C7.1 Merit-Order Flowchart C7.8
Figure C7.2 Linear Programming Flowchart C7.9

Figure C8.1 Schematic Representation of the Financial Module C8.3
Figure C8.2 Subroutine DEPREC Flowchart C8.29
Figure C8.3 Finance Inputs and Outputs C8.30

Figure C9.1 AUSM Report Generation Phases C9.2
Figure C9.2 Program AUSMR C9.14
Figure C9.3 Function MORSTA C9.15
Figure C9.4 Function ROUTER C9.16

Figure D10.1 Default Scenario Directives File, E8 . . . . D10.3
Figure D10.2 SCNGEN Flowchart D10.7
Figure D10.3 Flowchart for a SCNGEN Menu Page D10.8

Figure D11.1 AUSM Report Generation Phases D11.2

TABLES

Table Page

Table A.1 Strategies: Regional Emission Ceiling Policy Focus A.3

Table B1.1 Possible Values for Mine Size, Mine Depth, Seam Thickness and Overburden Ratio B1.4
Table B1.2 Calculation of Reserves B1.6
Table B1.3 Mapping of EIA to AUSM Supply Regions B1.7
Table B1.4 Mapping of EIA to AUSM Sulfur Categories B1.9
Table B1.5 Mapping of EIA to AUSM Higher Heating Value Codes B1.9
Table B1.6 Program QUANT: Variable Information B1.13
Table B1.7 Program QUANT: Variable Descriptions B1.16
Table B1.8 Sample Resource Allocation Results from Program QUANT B1.25
Table B1.9 Program QUANT Files B1.27
Table B1.10 Program QUANT: File Descriptions B1.28
Table B1.11 Cost Values for Deep Mines B1.39
Table B1.12 Cost Values for Surface Mines B1.40
Table B1.13 Productivity Values and Supply, Water and Power Values for Deep Mines B1.42
Table B1.14 Productivity Values and Supply, Water and Power Values for Surface Mines B1.43
Table B1.15 MNCOST Output File (MMAT) B1.45
Table B1.16 Program MNCOST: Variable Information B1.46
Table B1.17 Program MNCOST: Variable Descriptions B1.47
Table B1.18 Program RGCOST: Default Values for Parameters and Scenario Variables B1.50
Table B1.19 Program RGCOST: Variable Descriptions B1.52
Table B1.20 Program RGCOST: Variable Information B1.59
Table B1.21 Equation for Capital Stream Used to Determine Capital Depreciation B1.71
Table B1.22 Program RGCOST: Input Files B1.74
Table B1.23 Program RGCOST: Output File (MINCOS) B1.75
Table B1.24 Model Mine, EIA and AUSM Supply Regions B1.80
Table B1.25 File CPRICE Format B1.88
Table B1.26 File GPRICE Format B1.90
Table B1.27 File EXIST Format B1.91
Table B1.28 WASH1, WASH2 and WASH3 Format B1.92
Table B1.29 File CTRANS Format B1.93
Table B1.30 File USERLC Format B1.94
Table B1.31 COST File Format B1.95
Table B1.32 File INTRM1 Format B1.97
Table B1.33 File INTRM2 Format B1.97
Table B1.34 Synopsis and Calling Sequence of LEASTC Subprograms B1.98
Table B1.35 LEASTC Variable Descriptions B1.117
Table B1.36 LEASTC Variable Information B1.122
Table B1.37 Input Parameter Format B1.130
Table B1.38 *E6ALL* and *E6LOC* Formats B1.131
Table B1.39 File DEL80 Format B1.134

Table B1.40 Program MAKE6: Variable Descriptions B1.135
Table B1.41 Program MAKE6: Variable Information B1.137

Table C3.1 Storage Locations of Data Groups C3.10
Table C3.2 Projection Years, Projection Values and Data Groups C3.11
Table C3.3 Global Scenario Parameters C3.13
Table C3.4 State Scenario Parameters C3.19
Table C3.5 Synopsis and Calling Sequence of Control Subprograms C3.25
Table C3.6 Control Program Variables C3.62

Table C4.1 Correspondence Chart for Fuel Prices C4.28
Table C4.2 Correspondence Chart for Demand Model Inputs C4.29
Table C4.3 Calibration Chart C4.30
Table C4.4 Correspondence Chart for Demand Model Components C4.31
Table C4.5 Program DEMAND: Variable Descriptions C4.33
Table C4.6 Subroutine DEMAND: Variable Information C4.40
Table C4.7 Subroutine PRERR: Variable Descriptions C4.45
Table C4.8 Subroutine PRERR: Variable Information C4.45
Table C4.9 Subroutine GETQ: Variable Descriptions C4.46
Table C4.10 Subroutine GETQ: Variable Information C4.47

Table C5.1 Subroutine Synopses and Calling Sequences C5.12
Table C5.2 Variable Descriptions C5.37
Table C5.3 Plan Variable Information C5.44

Table C6.1 Synopses of Major Subprograms C6.21
Table C6.2 Synopses of Utility Subroutines C6.26
Table C6.3 Variable Descriptions C6.62
Table C6.4 Variable Information C6.86

Table C6a.1 TDP Pollution Control Variable Descriptions C6a.12

Table C7.1 Subprogram Descriptions C7.10
Table C7.2 Sequence of Calls in the XMP Package C7.14
Table C7.3 DSPACH Variable Descriptions C7.16
Table C7.4 DSPACH Variable Information C7.18
Table C7.5 XMP Variables C7.20
Table C7.6 Variables Used in Program DSPACH to Call XMP Programs C7.25

Table C8.1 Financial Module Data Handling C8.24
Table C8.2 Subroutine Synopses C8.26
Table C8.3 Variable Descriptions C8.31
Table C8.4 Variable Information C8.52

Table C9.1 Synopses of AUSMR Control Program Subprograms C9.7
Table C9.2 Variable Information for AUSMR Control Program C9.17

Table D10.1 E8 Scenario Parameters and Modifying Routine D10.9
Table D10.2 Variable Information for SCNGEN D10.20

Table D11.1 Synopses of REPGEN Subprograms D11.4

ABBREVIATIONS

ITEM	DESCRIPTION
AFUDC	Allowance for funds used during construction
AUSM	Advanced Utilities Simulation Model
Btu	British thermal units (1 Btu = 1.055 kJ)
Ca/S	Calcium to sulfur ratio
CF	Capacity factor
FIPS	Federal Information Processing Standard
HHV	Higher heating value
ITC	Investment tax credit
kW	Kilowatt (1 kW = 1 kJ per second)
kWh	Kilowatt hours (1 kWh = 3.6 MJ)
LDC	Load Duration Curve
LIMB	Lime Injection Multi-stage Burner
MMBtu	Million British thermal units (MMBtu = 1.055×10^6 kJ)
MPMS	Multi-period, Multi-state
MW	Megawatts
MWh	Megawatt hours (1 MWh = 3.6 GJ)
NCSM	National Coal Supply Model
NSPS	New Source Performance Standard (1971)
NO_x	Nitrogen oxides
RNSPS	Revised New Source Performance Standard (1979)
SAIC	Science Applications International Corporation
SO_2	Sulfur dioxide
SAS	SAS Institute, Inc., developer of a series of data analysis and management packages for the computer
SIP	State Implementation Plan
URGE	Universities Research Group on Energy
US	United States
XMP	FORTRAN based linear programming package

ACKNOWLEDGEMENTS

The Environmental Protection Agency (EPA) wishes to acknowledge the considerable work by the Universities Research Group on Energy (URGE) research team led by James J. Stukel, that contributed to this document. The efforts of the following chapter/appendix authors are recognized:

Chapter A. Introduction
James J. Stukel, University of Illinois at Urbana-Champaign,
105 Observatory Building, 901 S. Mathews Avenue, Urbana, IL 61801.

Chapter B1. The Coal Supply Module
Beth Engelbrecht-Wiggans, Howard Ojalvo and Kevin Welch,
University of Illinois at Urbana-Champaign.

Chapter B2. The MPMS Module
R. Edahl, N. Tyle, S. Talukdar and N. Pacharis, University of Illinois at Urbana-Champaign.

Chapter C3. The Control Program
Caroline Badger and William H. May, University of Illinois at Urbana-Champaign.

Chapter C4. The Demand Module
M. Czerwinski, T. Mount, A. Schwartz, T Motyka and D. Turck,
Cornell University, Ithaca, NY 14853.

Chapter C5. The Capacity Planning Module
Beth Engelbrecht-Wiggans, Howard Ojalvo and Kevin Welch,
University of Illinois at Urbana-Champaign.

Chapter C6. The Pollution Control Module
J.F. Skea, W. Gooding and C.N. Bloyd,
Carnegie-Mellon University, Pittsburgh, PA 15217.

Appendix C6a. Simulating Market Management Systems Using the Advanced Utility Simulation Model
James S. Diemer, University of Illinois at Urbana-Champaign.

Chapter C7. The Dispatching Module
N. Tyle, S.N. Talukdar and R. Edahl, Carnegie-Mellon University.

Chapter C8. The Financial Module
Mark Younger and Kathleen Cole, Cornell University.

Chapter C9. The Report Writer
Howard Ojalvo, University of Illinois at Urbana-Champaign.

Chapter D10. The Scenario Selector
William H. May, University of Illinois at Urbana-Champaign.

Chapter D11. The Report Selector
Howard Ojalvo, University of Illinois at Urbana-Champaign.

EPA also acknowledges the work of Robert T. Lassinger, Science Applications International Corporation, in editing the final text of this document, and Richard Silberman, Science Applications International Corporation, for graphics support.

A. INTRODUCTION

by
James J. Stukel

Universities Research Group on Energy
University of Illinois at Urbana-Champaign

A.1 Background

The Advanced Utility Simulation Model (AUSM) is a policy analysis tool designed to analyze the implications for the U.S. electric utility sector of alternative strategies for reducing air pollutant emissions in the generation of electricity. The need for such a model was emphasized by an expanded effort within the sponsoring agency, the U.S. Environmental Protection Agency (EPA), other federal agencies directed toward acid rain mitigation and by an impending congressional review of the Clean Air Act.

The AUSM developmental work was carried out through a cooperative agreement between EPA and the University of Illinois at Urbana-Champaign; the agreement was initiated in September 1980. The arrangement included subcontracts with Cornell University and Carnegie-Mellon University. The researchers performing the work were known collectively as the Universities Research Group on Energy (URGE)[1]

The state-level AUSM has been completed, tested and implemented in the public domain. This state-of-the-art model operates at the state level, with special emphasis on the role of coal for the generation of electricity. The model is used to analyze critical policy alternatives concerned with the mitigation of acid rain and other air pollution issues. The AUSM was designed originally to deal with the policy strategies listed in Table 1-1. However, the model is also able to deal with many other strategies and issues.

---

[1] The URGE researchers were led by the author of this chapter, James J. Stukel, Professor of Civil Engineering and Mechanical Engineering and Director, Public Policy Program, College of Engineering, University of Illinois at Urbana-Champaign.

A-2. Scope of Documentation

The first volume of the AUSM documentation series [1] covers the analytical rationale for each substantive analytical module in the AUSM: demand, finance, coal supply, pollution control, dispatching and capacity planning. The AUSM electric utility unit inventory, the coal reserves data base and the methodology for handling coal cleaning are discussed in the appendices. The system design of the AUSM [2] is covered in a separate volume. Another volume [3] will present information on how to operate and update the model.

This present AUSM documentation provides the discussion of the computer programs developed for the model. In addition to chapters on the programs of each analytical module, there are chapters on the other parts of the model: the control program, the report writer, the scenario selector, and the report selector.

The interaction of these integrated programs allows the AUSM to provide plausible results for policy analysis while meeting criteria of reasonable cost, independence form a specific contractor to run the model, independence from a specific type of computer and independence from the original developer. These four system design criteria are discussed in the remainder if this introduction, which also describes the main operating features of the model.

A-3. System Design and Operation

System design and operation issues usually are not given much explicit attention in model development efforts as are analytical capabilities. Probably the most serious deficiencies of the current generation of utility models fall into the design category. Current model that are detailed enough for regulatory analysis are uniformly cumbersome and frequently require excessive computer resources and inordinate amounts of contractor-supplied analyst time to set up, run and interpret the output of the scenarios. This results in inordinately long turn-around time -- sometimes a matter of weeks for a complete

Table A-1

STRATEGIES: REGIONAL EMISSION CEILING POLICY FOCUS

---

1. Technical Regulatory Changes: Absolute Emission Limitations
    - 1.1 By state
    - 1.2 By region
    - 1.3 By generating unit
    - 1.4 By type of unit (SIP and NSPS)
        - 1.4.1 Changes in averaging times of SIP units
        - 1.4.2 Redefinition of plant modification
        - 1.4.3 SIP rollback
        - 1.4.4 Nonenforcement of SIPs
        - 1.4.5 Emission charges-transferable discharge permits
2. Financial Regulatory Changes
    - 2.1 Revenue-setting policies
    - 2.2 Corporate income tax investment incentives
    - 2.3 Pollution control costs
        - 2.3.1 Changing investment tax credit
        - 2.3.2 Rate base treatment, tax depreciation
        - 2.3.3 Interest rates
3. Control Options
    - 3.1 Coal cleaning: a specific level of cleaning for all coals above a given sulfur content
    - 3.2 Coal blending
    - 3.3 Low-sulfur coal
    - 3.4 Local coal use
    - 3.5 Nuclear fuel
    - 3.6 Oil and gas fuel
4. Technology-Based Regulatory Changes
    - 4.1 Wet and dry FGD systems
    - 4.2 NOx control technologies
    - 4.3 Particulate control technologies: electrostatic precipitators and fabric filters
5. System Operating Performance and Utility Behavior-Based Regulatory Changes
    - 5.1 Least emission dispatch
    - 5.2 Shortening or prolonging of plant lifetime
    - 5.3 Utility strategy for least-cost compliance with regional emission ceilings
6. Least-Cost Combinations of Fuel and Technology Choice

Reproduced from
best available copy.

scenario run—and excessive costs. A major criterion of the AUSM system design is that improved state-of-the-art analytical capabilities be provided at reasonable cost.

Another common flaw in existing models is that they are structured and documented (or undocumented) so that their internal operations are virtually impossible to understand by anyone except the contractors who developed them. Embedded assumptions and idiosyncracies may make it difficult to trace the relationship between a change in an input parameter and changes in model outputs. Thus some models can be run successfully only by the contractor organization that developed them. A second criterion of the AUSM system design is that it be a contractor-independent model, one that can be operated and understood by any interested organization.

Large computer programs are often intended to be operated on a specific type of machine. Even when a model is not proprietary, much time and effort may be required to make it operational on another machine. A third criterion of the AUSM design is that it be as machine independent and thus as transferable as possible.

The last major objective of the AUSM system design is that the model be independent of its developers.

Because the project team and project officer recognize that system design improvements are at least as important as enhanced analytical design, significant project resources have been allocated to system design and integration efforts in an effort to meet those criteria. Thus, in making decisions about specific system design features, the attempt was to develop features to fulfill all four criteria: efficiency, contractor independence, transferability, and developer independence. Some of these features are presented below in terms of the four criteria.

After assuring that the model accurately provided the analytical capabilities promised by the developers, the most important objective of system design was cost savings. In the case of the Utility Simulation Model at least, the computer costs associated with the final execution of the computer model to simulate a desired scenario were often negligible compared with the analyst and programmer costs and with the computer charges incurred in defining the scenario, revising the data base and code to implement that scenario, and testing and debugging the modified model.[2] The URGE team has sought advice from EPA and from other potential users of the model to devise a set of common scenario parameters that should allow the model to be used as an effective policy analysis tool for several years with little or no modification. Thus, most anticipated scenarios concerned with acid rain mitigation can probably be specified by EPA and other government users with minimal interaction with model analysts and computer professionals.

Because data handling often consumes more computer resources than computational tasks in a large simulation model, particular effort went into the design of data-handling procedures. Other efficiency features are designed into the model. For example, data generated for reports and graphs are simply dumped into binary format disk files for later processing by a specialized report-writing program. Not only does this drastically cut the costs associated with abortive test and developmental runs, it also allows different (or reformatted) sets of reports to be generated later from the same scenario, often without re-executing the model. A standard method also has been devised for modules optionally to specify varying levels of additional model output needed only for tracing potential errors and for validating the results of the model. Since these printed data are produced only when specifically requested, normal runs are relatively inexpensive.

Finally, unnecessary computations are avoided. For example, it is recognized that the coal supply module need not be solved simultaneously with the detailed utility sector simulation. Therefore, this module is broken off as a preprocessor to the AUSM and is rerun only when the user wishes to change coal-related scenario parameters for a specific series of AUSM runs.

Through the careful design of scenario-specific parameters discussed above and through the detailed analytical [1] and program documentation being prepared, it is hoped that the contractor-independent criterion will be met.

Particular effort has been expended to assure that the third criterion, transferability, is met. First, very rigid structural and coding standards were maintained during module development [2]. All code is written in a subset of 1966 American National Standards Institute (ANSI) FORTRAN. The subject was selected based on a comparison of the FORTRAN compilers provided by three major vendors. All library routines included with the model are FORTRAN callable, in the public domain, and are available for both the CDC and IBM systems.

---

[2] See Reference 4 for a comparison of the Utility Simulation Model with the Coal and Electric Utility Model.

While transferability was a consideration in selecting many of the individual design elements, one element in particular should be noted: The control program is the only segment of the model with direct access the physical data files. Analytical modules are independent of the physical structure of the data base. The modules locate and retrieve data via the control program by describing the logical attributes of the data desired. Although input-output procedures in FORTRAN programs can never be made completely machine independent, the routine conversion tasks necessary to transfer the model between the University of Illinois CDC computer and the EPA IBM computer are now confined to one program. Virtually no modifications will be required in the analytical modules. The control program is discussed in Chapter C-3.

To further assure transferability to the EPA system, the URGE Project Office staff periodically tested the complete model on the IBM 4341 located on the University of Illinois campus.

The final criterion, developer independence, is assured by both this detailed documentation series and the use of automated, easily obtainable data sets whenever possible. These data sets are compatible with those used by other agency that could also employ the AUSM, notably the Department of Energy (DOE).

It is recognized that the objectives discussed above were extremely ambitious. Many were very difficult to achieve, but the project team and project officer have dedicated much time and effort toward meeting them. To identify the most productive approaches to achieving these goals and evaluating progress toward them, substantial involvement was sought from individuals outside the project. Outside review and comment principally came from individuals working on related federally supported projects and from a very active working group of potential government users of an advanced model (principally EPA and DOE regulatory and policy analysis staffs). In addition, an on-going technical review process involved recognized experts in various aspects of utility and coal supply modeling from academe, research and environmental organizations and industry.

The AUSM operating environment consists of the simulation program and a number of pre- and postprocessors. Figure A-1 presents a simplified overview of the execution of the complete state-level model. The steps in the process are explained below.

Step 1. Coal Supply. The coal supply module is executed as a separate preprocessor to the AUSM. Since the same user-specified assumptions concerning coal supply normally will hold over a series of scenarios, this step is executed infrequently.

Step 2. Scenario Specification The user executes the interactive program SCNGEN to create a scenario directive file to be read by AUSM. Alternatively, a standard text editor may be used to modify the default directive file, file E8.

Step 3. Simulation. In normal operation, the nine files from the model's master data base are inputs to the simulation program, including a scenario directive file generated by SCNGEN.

A tenth (optional) input file contains fuel-specific weights, each corresponding to a given set of exogenous electricity demand specifications that were generated in an earlier AUSM run. These weights must be used to implement exogenous demand with annual recursiveness.

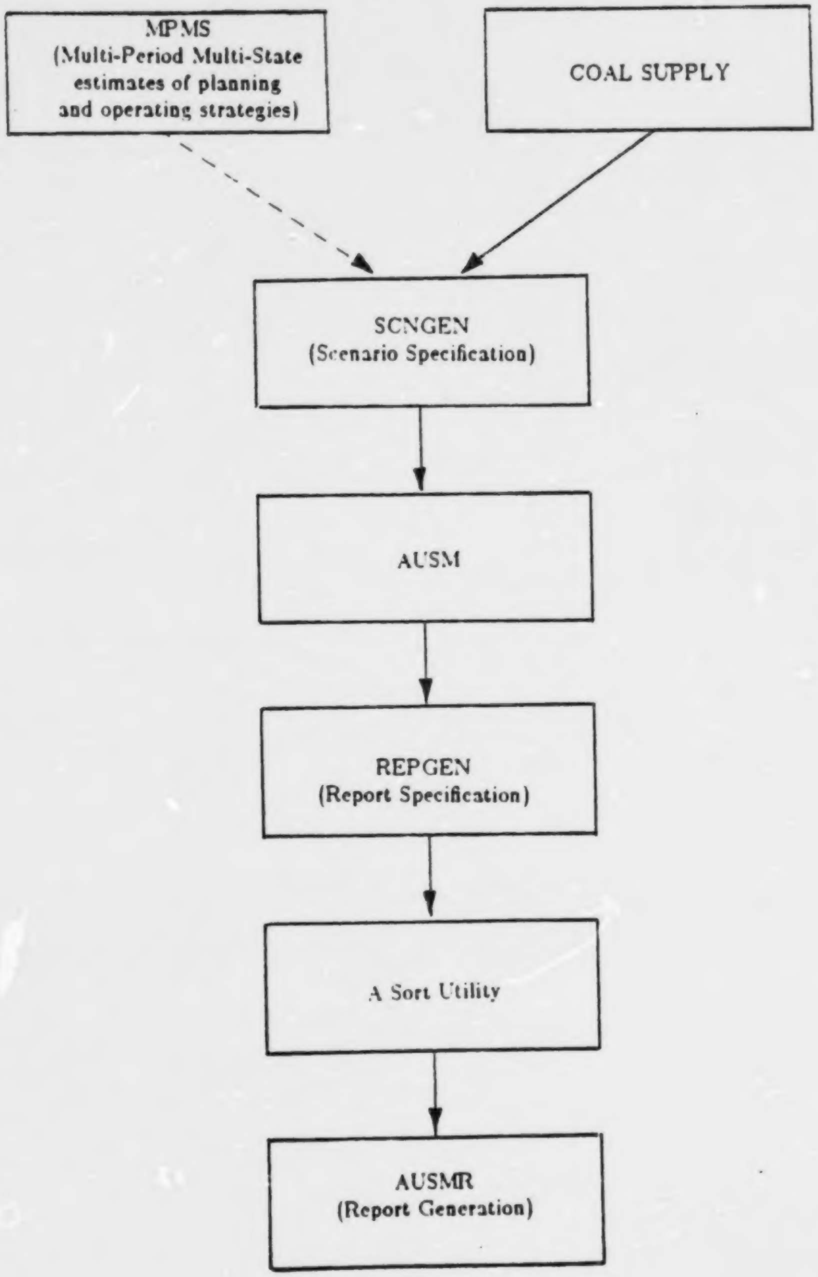
An eleventh (optional) input file is generated by the Multi-Period, Multi-State (MPMS) module, the AUSM screening module that develops preliminary strategies for adding equipment, for plant operation over time, and for transferring power among states. MPMS may also generate a revised inventory of announced generators for use by AUSM.

Step 4. Report Specification. REPGEN is an interactive program for specifying report options. The user selects the individual reports to be generated as well as the states and years to be included. REPGEN creates a report directive file which is read by AUSMR, the report generator (see Step 6).

Step 5. Data Sort. A standard sort utility must be used to sort the unformatted report data generated by AUSM.

Step 6. Report Generation. AUSMR is the report generator for the AUSM. It is executed as a postprocessor to AUSM. Input to AUSMR consists of the unformatted report data generated by AUSM, properly sorted and a report directive file generated by REPGEN.

Figure A-1
OVERVIEW OF AUSM EXECUTION



The state-level simulation program consists of a Fortran control program, AUSM, which invokes six analytical modules: demand, plan, comply (pollution control), dispatch, (environmental) impacts, and finance.

The control flow for each year of the state-level model simulation period is depicted in Figure A-2. The control module performs the following functions: (1) invocation of the analytical modules when required, (2) provision of all data-handling routines, (3) implementation of scenario-specified parameters, and (4) provision of error-handling routines.

REFERENCES

1. James J. Stukel. **"Advanced Utility Simulation Model, Analytical Documentation, State Level Model (Version 1.0)."** U.S. Environmental Protection Agency. EPA-600/8-88-071a. January 1989.

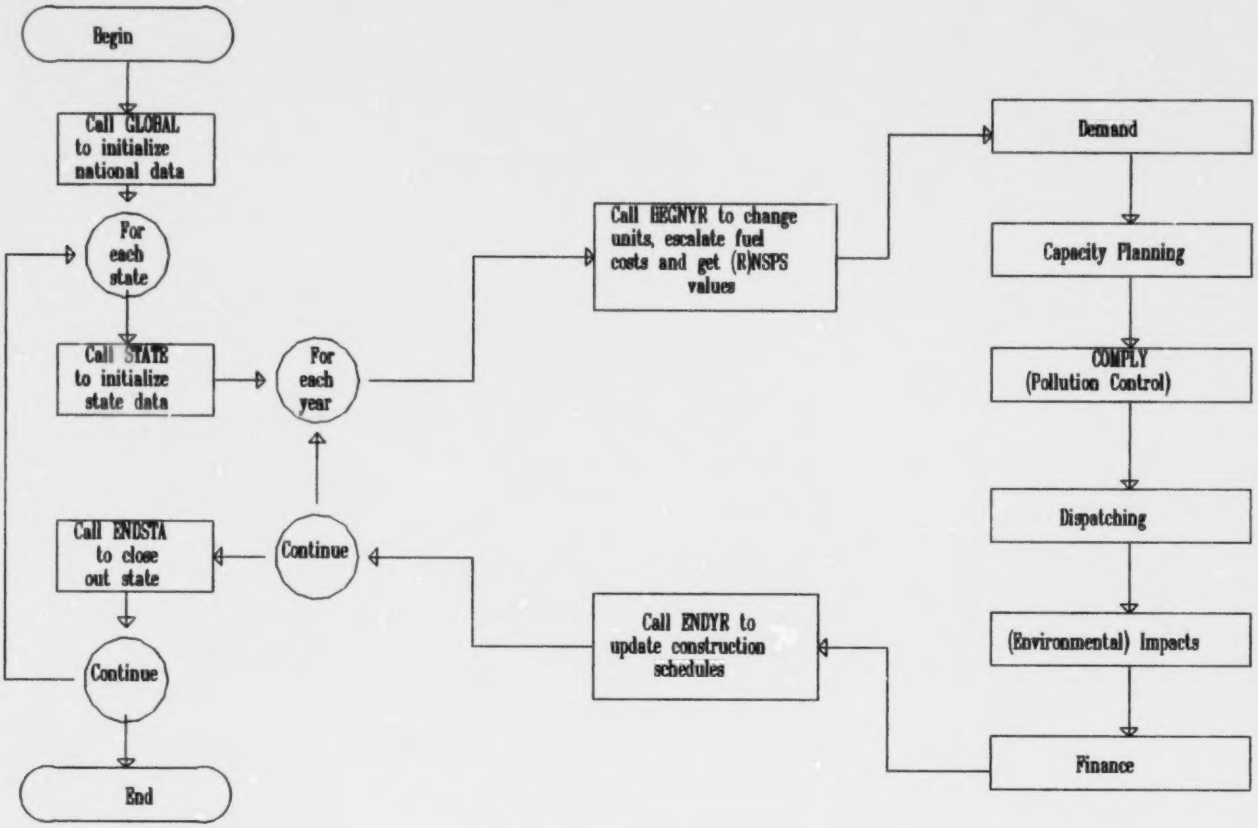
2. Caroline J. Badger and Howard Ojalvo. **"Advanced Utility Simulation Model, Documentation of System Design, State Level Model (Version 1.0)."** U.S. Environmental Protection Agency. EPA-600/8-88-071c (NTIS PB89-101208). August 1988.

3. Caroline J. Badger and William H May. **"Advanced Utility Simulation Model, Model Operations (Version 1.0)."** U.S. Environmental Protection Agency. EPA-600/8-88-071e (NTIS PB89-118749). October 1988.

4. Barry Silverman. **"Acid Rain and a Comparative Analysis of Two Large-Scale Electric Utility Models."** Journal of the Air Pollution Control Association. Vol. 32, No. 10. October 1982.

Figure A-2

AUSM LOGIC FLOW


Begin
Call GLOBAL to initialize national data
For each state
Call STATE to initialize state data
For each year
Call BEGNYR to change units, escalate fuel costs and get (R)NSPS values
Demand
Capacity Planning
COMPLY (Pollution Control)
Dispatching
(Environmental) Impacts
Finance
Call ENDYR to update construction schedules
Continue
Call ENDSTA to close out state
Continue
End

B1. THE COAL SUPPLY MODULE

by
Beth Engelbrecht-Wiggans, Howard Ojalvo and Kevin Welch

Universities Research Group on Energy
University of Illinois at Urbana-Champaign

1.1 Overview

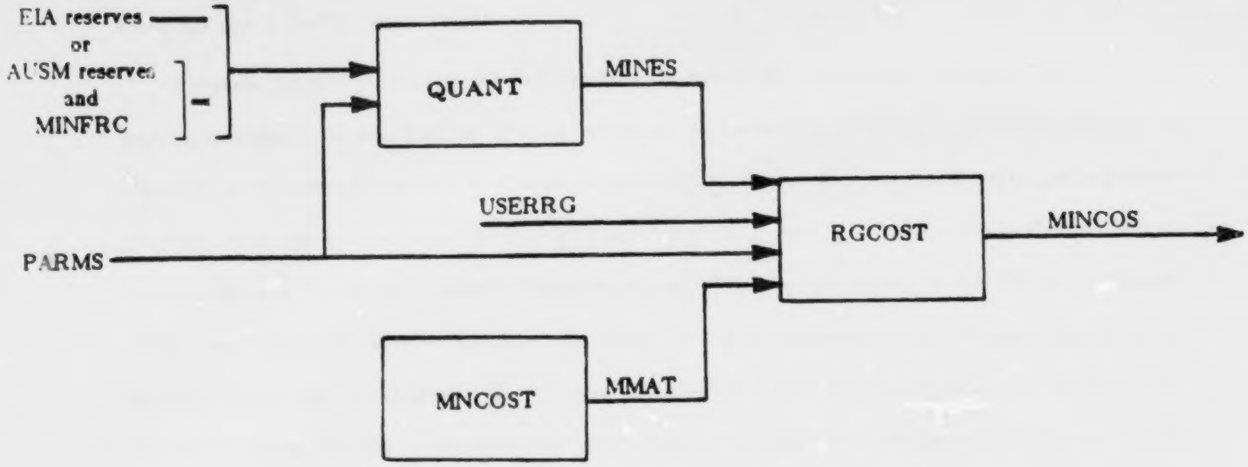
The coal supply module of the Advanced Utility Simulation Module (AUSM) models the processes by which the coal having the least delivered cost is identified by each of 48 demanders. Module inputs consist of data for the amount of coal reserves available in each of a set of supply regions. The final output is file E6, which contains the least delivered cost coals that are available to each demand region for each specified year. Delivered cost is a sum of minemouth, washing and transportation costs. E6 is used as input to other AUSM modules.

The coal supply module can be divided into two parts, the minemouth cost preprocessor and the least delivered cost preprocessor. The function of the minemouth cost preprocessor is to determine the lowest minemouth cost coal from each supply region. The preprocessor performs three basic functions: (1) the distribution of coal reserves in to mines, (2) the costing of coal from these mines and (3) the determination of the lowest minemouth cost coal from these mines.

Three major programs -- QUANT, MNCOST and RGCOST -- carry out functions. Program QUANT distributes reserves into mine types (surface and deep) and mine characteristics (mine size, seam thickness, seam depth and overburden ratio). Program MNCOST determines model mine costs based on the mine type characteristic and model mine equations. These two programs are essentially the same as those employed in the Resource Allocation and Mine Costing (RAMC) model, a program developed for the Energy Information Administration (EIA) of the U.S. Department of Energy [1]. The programs are implemented here in such a way that the mining and costing parameters and/or mine cost equations can be changed easily for future analyses. Finally, program RGCOST uses fixed and variable costs, MNCOST outputs and inputs specified by the user to compute the least expensive minemouth cost for each coal type within a supply region. The relationship among programs QUANT, MNCOST and RGCOST is shown in Figure B1-1.

Figure B1-1

MINEMOUTH COST PREPROCESSOR PROGRAMS AND DATA FILES



Instead of using the minemouth cost processor, minemouth costs may be defined by the user, through specification of the rate at which such costs escalate from their 1980 values. This option is described in more detail later.

The outputs of the minemouth cost preprocessor are the characteristics of the least expensive coal, including price, supply region, coal type, and coal characteristics, given specified scenario variables. The least-delivered-cost processor uses the output from the minemouth cost preprocessor to determine delivered coal cost, which is a function of minemouth, washing, and transportation costs. It consists of two programs, LEASTC and MAKE6.

Program LEASTC combines information from the lowest minemouth-cost output of RGCOST with data on transportation and washing costs to determine the lowest cost at which a given coal type can be delivered to any demand region over a series of target years. This is done via an unconstrained algorithm described in an unpublished paper by Richard Engelbrecht-Wiggans [2]. LEASTC allows the user to generate output cost files under a variety of scenario options. For example, there is a detailed forced washing option that allows the user to simulate the effects of future mandatory coal cleaning regulations on delivered coal prices. Transportation costs may be escalated in two steps to simulate the effects of railroad deregulation. Finally, minemouth coal prices may be escalated at a constant rate if the user wishes to ignore the RGCOST estimates of minemouth prices in the years 1985 and beyond.

Following LEASTC, the program MAKE6 is run to 1) reformat the LEASTC output to create file E6, 2) overwrite the period 1 cost with the cost actually paid in period 1, and 3) interpolate a period 2 cost based on the actual period 1 cost and the period 3 cost from LEASTC.

1.2 Distribution of Reserves (Program QUANT)

The purpose of QUANT is to adjust the coal reserves data to account for mining recovery factors and reserves that are already committed, inaccessible, or illegal to mine, and to allocate remaining reserves into individual "deposits" characterized by mine size S, seam thickness T, and depth D or mine overburden ratio R. The possible values of S, T, D, and R for the minemouth cost preprocessor are given in Table B1-1.

Reproduced from
best available copy.

Table B1-1

POSSIBLE VALUES FOR MINE SIZE, MINE DEPTH, SEAM THICKNESS, AND OVERBURDEN RATIO

	Category							
Characteristic	1	2	3	4	5	6	7	Unit
Size	4	3	2	1	.5	.1		million tons/year
Depth	0	400	700	1000				feet
Thickness	72	60	48	36	28			inches
Overburden ratio	5	10	15	20	25	30	45	percent

The output of QUANT is the tons of reserves allocated to deep Q(S,T,D) and surface S(S,R) deposits. The inputs to this program include reserves data, coal and supply region mining parameters, and a coal-specific allocation fraction for each of three general categories deep thick, deep thin and surface mines. At the option of the user, the demonstrated reserves file can be either in AUSM coal categories (11 sulfur categories, three higher heating values) or in EIA coal categories (eight sulfur categories, five higher heating values). Tables B1-4 and B1-5 list EIA/AUSM sulfur and higher heating value categories.

The original data source for costing parameters, existing mines and EIA reserve data was obtained from the input file to the RAMC model [1]. The RAMC input file included reserves data, mining parameters, costing parameters, and data on existing mines, which were used to make the preprocessor input files DEMBAS and PARMS.

The AUSM category coal reserves file was created from two sources (mining reserves and committed reserves. The reserves data were obtained from E.H. Pechan and Associates [3]. The criteria used by Pechan for determining reserves were only slightly different from the EIA method. Committed reserves were assumed to equal 15 years of current production. Actual 1980 production by coal type and region was obtained from Green [4].

1.2.1 Central Algorithms and Basic Assumptions

For each coal type, reserves are allocated first among the three general categories mentioned above: (1) surface, (2) deep thin (28 to 42 inches), and (3) deep thick (more than 42 inches). The EIA reserves data are categorized in this manner. The AUSM data file contains total reserves not broken into reserve categories. The file MINFRC contains the fraction of total reserves by state and coal type (sulfur content and higher heating value) that are in surface, deep thin, and deep thick reserves. The reserves that are either illegal to mine or already committed are then subtracted. The method of calculating the reserves available for mining is shown in Table B1-2.

As noted, the EIA reserves data are divided into three categories (deep thick, deep thin, and surface). These data were used to create a percentage file for the AUSM data (MINFRC). Tables B1-3, B1-4, and B1-5 show mappings from EIA categories to AUSM categories that were used in creating MINFRC. For a particular AUSM coal, a weighted average of the percentages of the EIA coals mapped into it was used as the AUSM percentage (deep thick, deep thin, and surface). The weight corresponded to the percentage of overlap in the categories. Surface reserves, and then underground (deep) reserves, are allocated to production and written to the output file.

A generalized flowchart of QUANT appears as Figure B1-2. The detailed steps in allocation are described below, first for surface mines and then for deep mines. Variable names and descriptions can be found in Table B1-6 (variable information) and Table B1-7 (variable descriptions).

The basic preparation yield variable referred to below is set to 1.0 for both EIA and AUSM coal categories. The EIA yields were set to unity to correct for an error in the EIA mine cost equations, which are expressed in dollars per clean ton rather than per raw ton. (Later, updated mine cost equations will be in dollars per raw ton. Thus, basic preparation yields must be obtained from the washing matrix and used in calculating reserve depletion.)[1] The AUSM basic preparation yields were set to unity because all AUSM washing is handled in the washing portion of LEASTC.

---

[1] This information was obtained from Robert Crockett [5].

Table B1-2
CALCULATION OF RESERVES

Array Element	Description	Mathematical Definition (EIA)	Mathematical Definition (AUSM)	Special Condition
T2 (1)	Surface resources, legal to mine	DEMR (3) * (1. - XISR)	DEMRP * PSURF * (1 - XISR)	
T2 (2)	Committed surface reserves	CMTD (2)	0	
T2 (3)	Surface reserves, available for new mines	T2 (1) - T2 (2)	T2 (1) - T2 (2)	Set equal to zero if negative
T2 (4)	Deep reserves in thick seams, accessible to mining	DEMR (2) * (1. - XIDR)	DEMRP * PDTHICK * (1 - XIDR)	
T2 (5)	Committed deep reserves	CMTD (1)	CMTD(1)	
T2 (6)	Deep thick reserves, available for new mines	T2 (4) - T2 (5)	T2 (4) - T2 (5)	Set equal to zero if negative
T2 (7)	Deep reserves in thin seams, accessible to mining	DEMR (1) * (1. - IDRC)	DEMRP * PDTHIN * (1 - XIDR)	
T2 (8)	Deep thin reserves, available for new mining	T2 (7) + TEMP	T2 (7) + TEMP	TEMP = 0 if T2(6) $\geq$0; otherwise TEMP = T2(4) - T2(5). T2(8) set equal to zero if negative.

Table B1-3

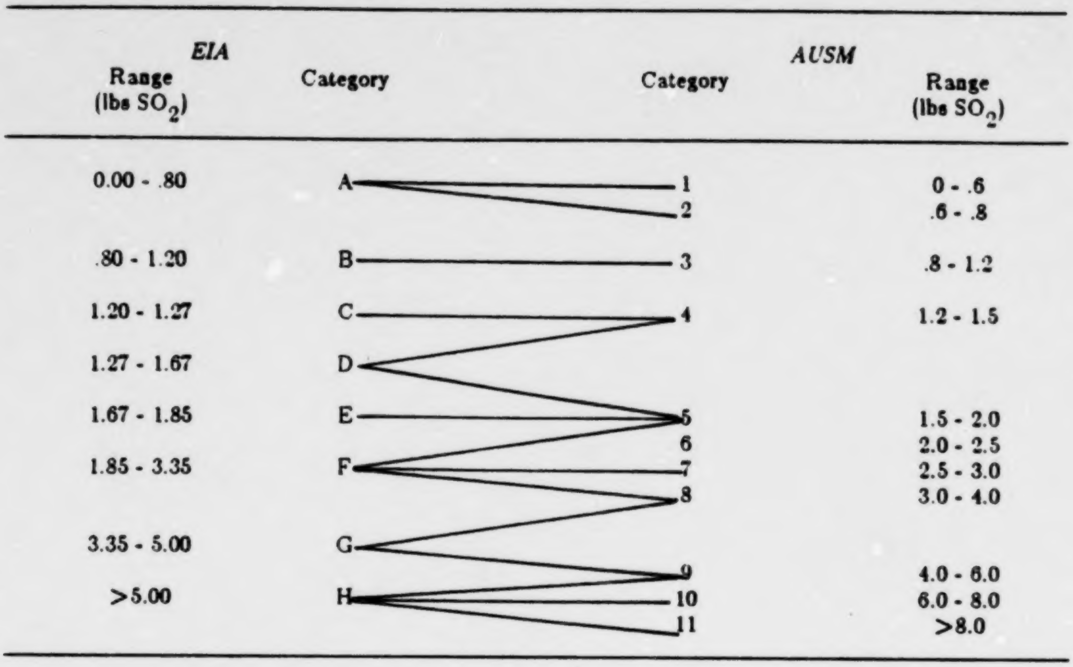
MAPPING OF EIA TO AUSM SUPPLY REGIONS

EIA Region	AUSM Region
Pennsylvania	1. Pennsylvania-East
	2. Pennsylvania-West
Maryland	3. Maryland
West Virginia, North	4. West Virginia-East
	5. West Virginia-North
	6. West Virginia-Panhandle
West Virginia, South	7. West Virginia-Southeast
	8. West Virginia-Southwest
Ohio	9. Ohio
Virginia	10. Virginia-East
	11. Virginia-West
Kentucky, East	12. Kentucky-East
Kentucky, West	13. Kentucky-West
Tennessee	14. Tennessee-North
	15. Tennessee-South
Illinois	16. Illinois
Indiana	17. Indiana
Iowa	18. Iowa
Alabama	19. Alabama
Arkansas	20. Arkansas
Oklahoma	21. Oklahoma-East
	22. Oklahoma-West
Kansas	23. Kansas
Missouri	24. Missouri

Table B1-3 (contd.)

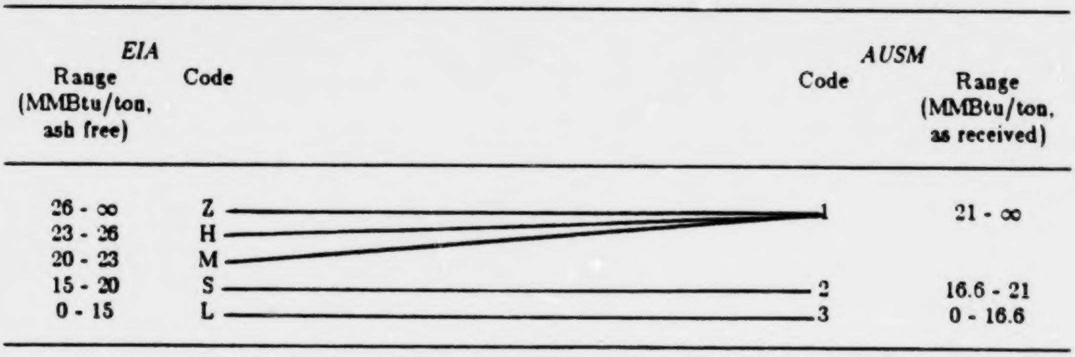
EIA Region	AUSM Region
Texas	25. Texas
Colorado	26. Colorado-North 27. Colorado-South
New Mexico	28. New Mexico-Northeast 29. New Mexico-West
Arizona	30. Arizona
Wyoming	31. Wyoming
Utah	32. Utah
North Dakota	33. North Dakota
Montana, East Montana, West	34. Montana
Washington	35. Washington

Table B1-4
MAPPING OF EIA TO AUSM SULFUR CATEGORIES



EIA		AUSM	
Range (lbs SO_2)	Category	Category	Range (lbs SO_2)
0.00 - .80	A	1	0 - .6
		2	.6 - .8
.80 - 1.20	B	3	.8 - 1.2
1.20 - 1.27	C	4	1.2 - 1.5
1.27 - 1.67	D		
1.67 - 1.85	E	5	1.5 - 2.0
		6	2.0 - 2.5
1.85 - 3.35	F	7	2.5 - 3.0
		8	3.0 - 4.0
3.35 - 5.00	G		
		9	4.0 - 6.0
>5.00	H	10	6.0 - 8.0
		11	>8.0

Table B1-5
MAPPING OF EIA TO AUSM HIGHER HEATING VALUE CODES



EIA		AUSM	
Range (MMBtu/ton, ash free)	Code	Code	Range (MMBtu/ton, as received)
26 - ∞	Z	1	21 - ∞
23 - 26	H		
20 - 23	M		
15 - 20	S	2	16.6 - 21
0 - 15	L	3	0 - 16.6

Figure B1–2
PROGRAM QUANT FLOWCHART

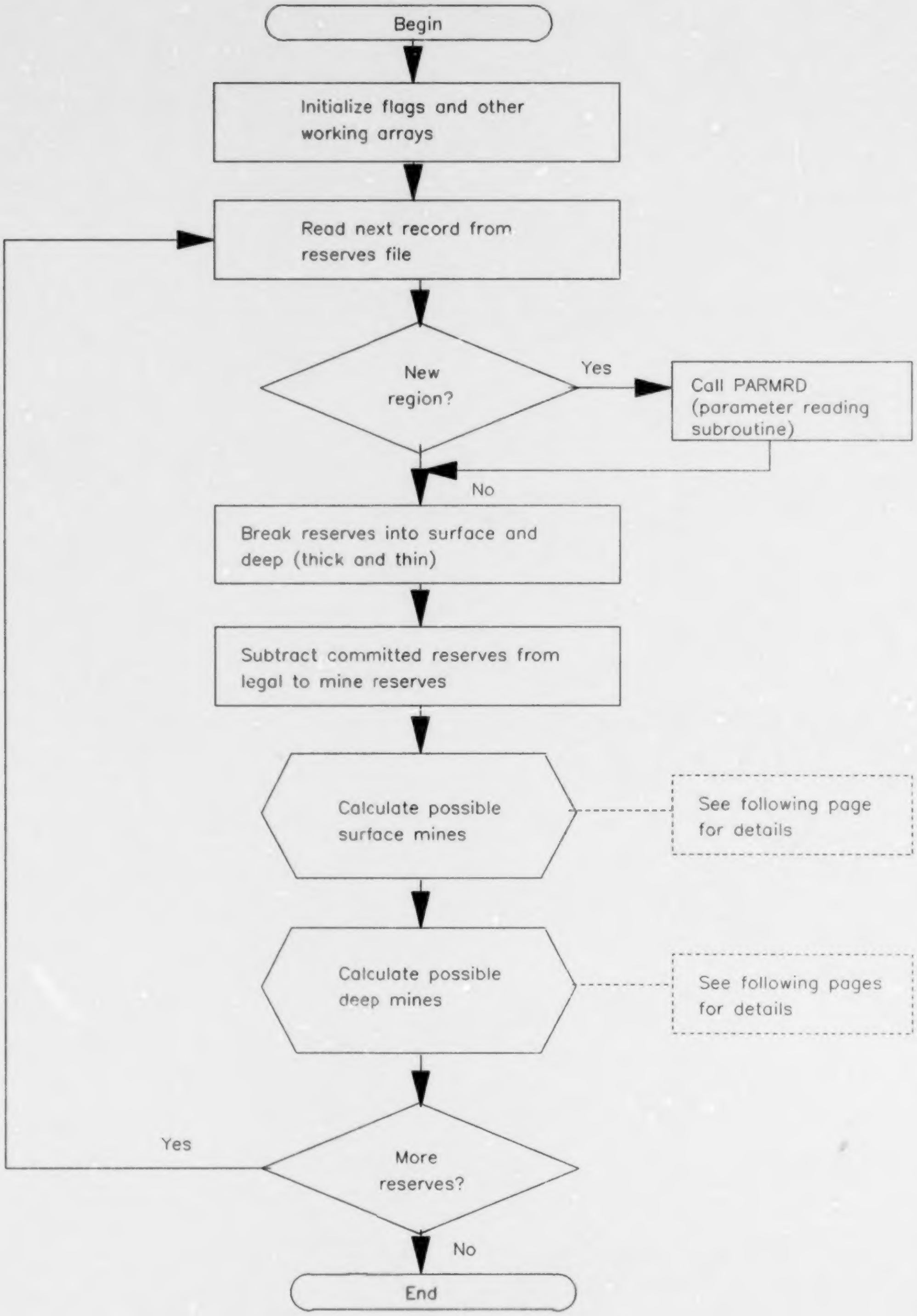

Begin
Initialize flags and other working arrays
Read next record from reserves file
New region?
Yes
Call PARMRD (parameter reading subroutine)
No
Break reserves into surface and deep (thick and thin)
Subtract committed reserves from legal to mine reserves
Calculate possible surface mines
See following page for details
Calculate possible deep mines
See following pages for details
More reserves?
Yes
No
End

Figure B1-2 (contd.)
PROGRAM QUANT FLOWCHART

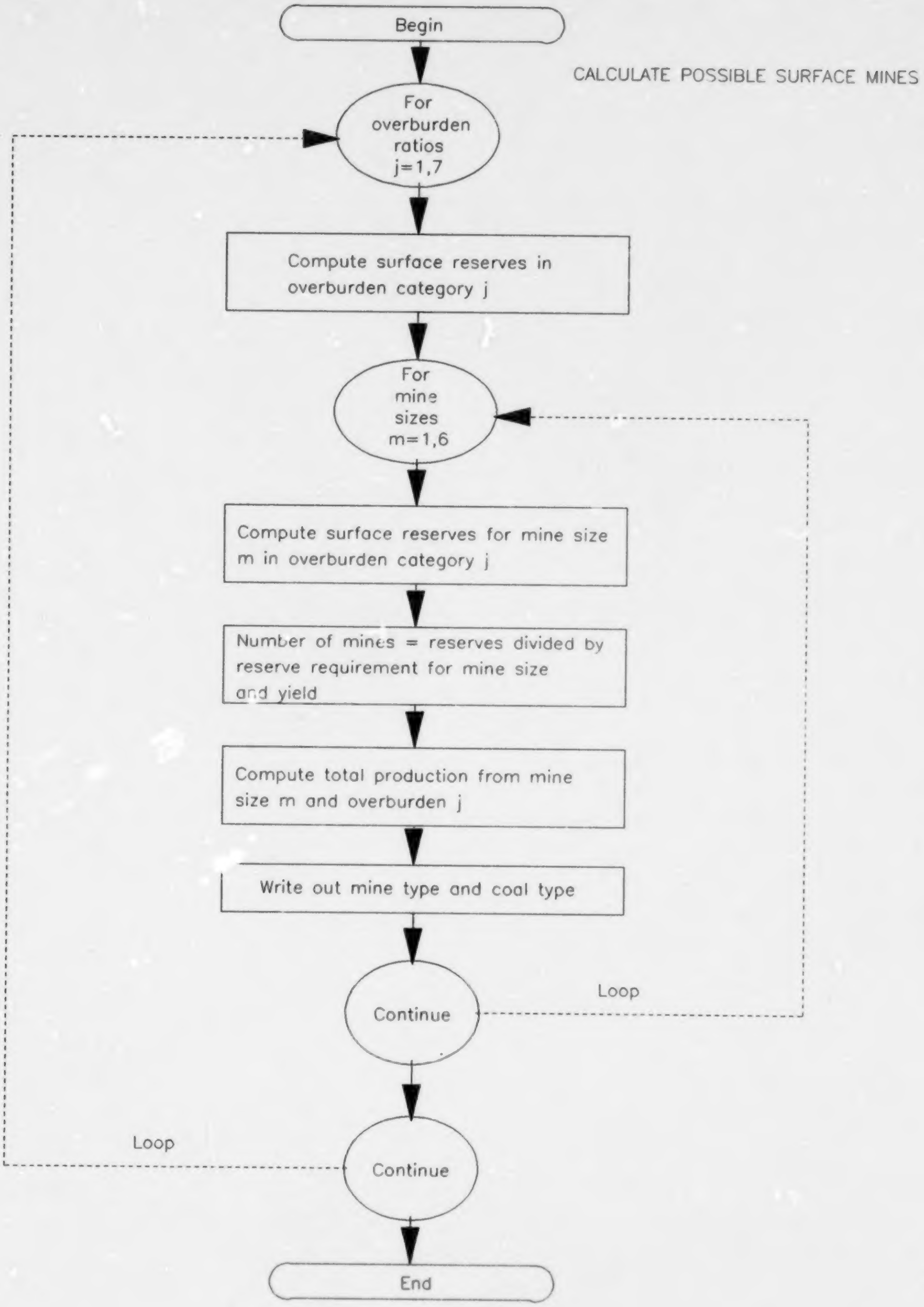

Begin
CALCULATE POSSIBLE SURFACE MINES
For overburden ratios j=1,7
Compute surface reserves in overburden category j
For mine sizes m=1,6
Compute surface reserves for mine size m in overburden category j
Number of mines = reserves divided by reserve requirement for mine size and yield
Compute total production from mine size m and overburden j
Write out mine type and coal type
Continue
Loop
Continue
Loop
End

Figure B1–2 (contd.)
PROGRAM QUANT FLOWCHART

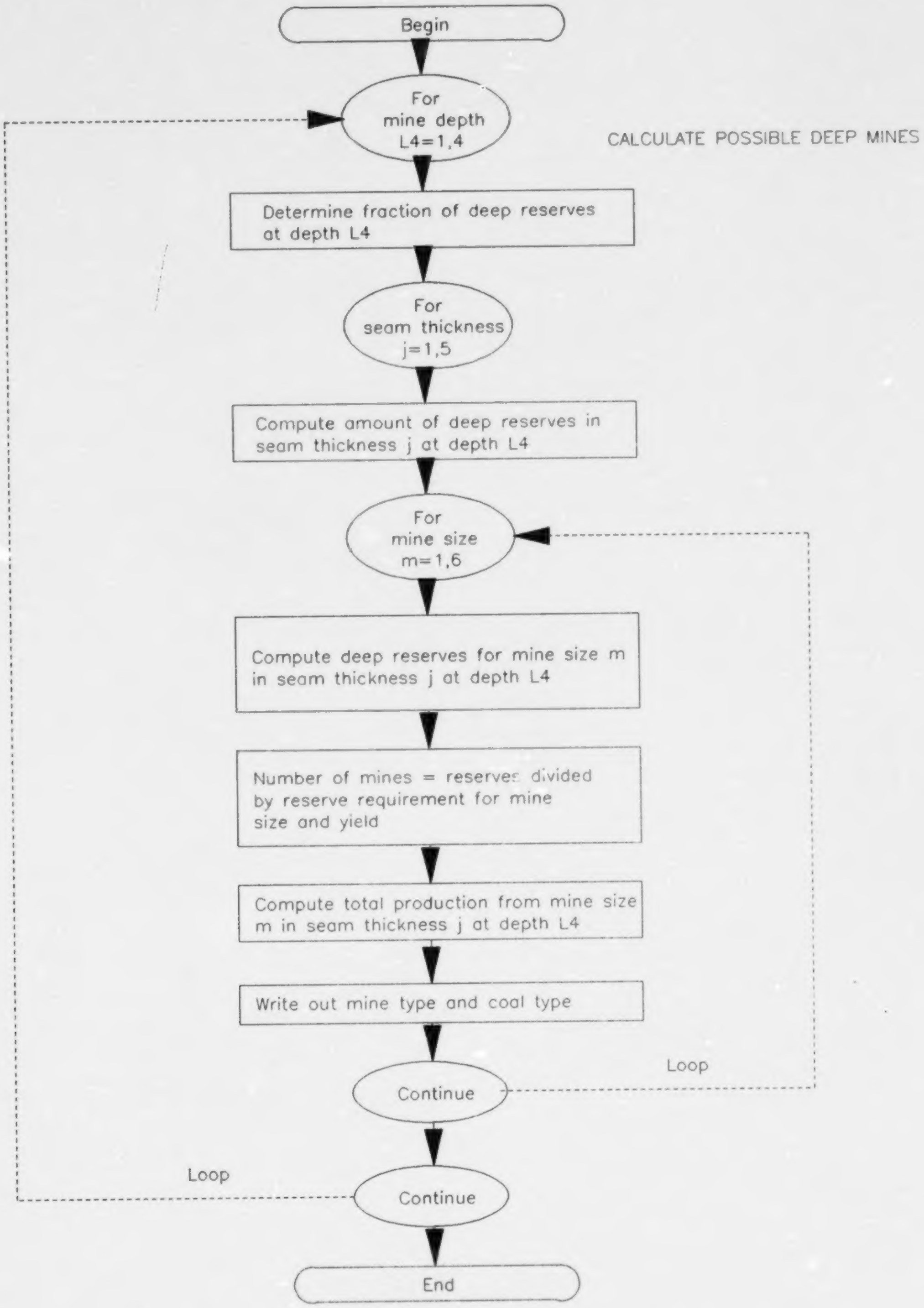

Begin
For mine depth L4=1,4
CALCULATE POSSIBLE DEEP MINES
Determine fraction of deep reserves at depth L4
For seam thickness j=1,5
Compute amount of deep reserves in seam thickness j at depth L4
For mine size m=1,6
Compute deep reserves for mine size m in seam thickness j at depth L4
Number of mines = reserves divided by reserve requirement for mine size and yield
Compute total production from mine size m in seam thickness j at depth L4
Write out mine type and coal type
Continue
Loop
Loop
Continue
End

Table B1-6
PROGRAM QUANT: VARIABLE INFORMATION

Variable	Type	Dimension	Unit	Storage Location	Accessed by
ASH	real	1	percent		QUANT
BB	real	6	MMtons		QUANT
BDNLET	real	7	percent		QUANT
BRDNC	real	40,7	percent		QUANT,PARMRD
CMTD	real	2	MMtons		QUANT
DEMR	real	3	MMtons		QUANT
DEMRD	real	1	MMtons		QUANT
DIPLET	real	4	hundred feet		QUANT
DIV	real	1	MMtons		QUANT
DPSMDT	real	5,6	percent		QUANT
ICOAL	integer	1	code		QUANT
IFLAG	integer	1	flag		QUANT, PARMRD
IHHV	integer	1	code		QUANT, PARMRD, SUFCON
INDEX	integer	1	index		QUANT, PARMRD, SUFCON
IPAR	integer	1	flag		QUANT, PARMRD
ISTATE	integer	1	code		QUANT
ISUF	integer	1	code		PARMRD
ISULF	integer	1	code		QUANT, PARMRD
ITYPE	integer	1	flag		PARMRD
KMARG	integer	4,5	percent	/PARMS/	QUANT, PARMRD
LMAX	integer	1	inches		QUANT
LMIN	integer	1	inches		QUANT
LNREG	integer	1	code		QUANT

Table B1-6 (contd.)

Variable	Type	Dimension	Unit	Storage Location	Accessed by
LSTATE	integer	1	code		QUANT
MDM	integer	4,5	percent		PARMRD
MOIST	integer	1	percent		QUANT
MYR	integer	1	years		QUANT
NEWMIN	integer	1	count		QUANT
NHHV	integer	1	code		QUANT
NREC	integer	1	number		PARMRD
NREG	integer	1	code		QUANT
NSUF	integer	1	code		QUANT
PRODN	real	1	MMtons/year		QUANT
PSURF	real	11,3	fraction	/PCT/	QUANT, PARMRD
PTHICK	real	11,3	fraction	/PCT/	QUANT, PARMRD
PTHIN	real	11,3	fraction	/PCT/	QUANT, PARMRD
RECFCT	real	2	fraction		QUANT
RESREQ	real	2,6	fraction		QUANT
SIZEC	real	40,6	percent	/PARMS/	QUANT, PARMRD
SMDPC	real	40,4	percent	/PARMS/	QUANT, PARMRD
SMTHC	real	40,6	percent	/PARMS/	QUANT, PARMRD
SMTHR	real	6	percent		QUANT
SO2LBS	real	1	lbs SO_2/MMBtu		QUANT
SZELET	real	6	100 MMtons/year		QUANT
SZEMIN	real	6	MMtons/year		QUANT
TEMP	real	1	MMtons		QUANT
THKLET	real	5	inches		QUANT

Table B1-6 (contd.)

Variable	Type	Dimension	Unit	Storage Location	Accessed by
TMARG	real	5,5,4	percent	/PARMS/	QUANT, PARMRD
T2	real	8	MMtons		QUANT
T3	real	13	percent		QUANT
T4	real	10	percent		QUANT
XHHV	real	1	Btu/lb		QUANT
XIDR	real	1	fraction	/PARMS/	QUANT, PARMRD
XISR	real	1	fraction	/PARMS/	QUANT, PARMRD
XX	real	1	MMtons		QUANT
YIELD	real	40,2	fraction	/PARMS/	QUANT, PARMRD
YIELDD	real	1	fraction		QUANT
YIELDS	real	1	fraction		QUANT
ZZ	real	1	MMtons		QUANT

Table B1-7

PROGRAM QUANT: VARIABLE DESCRIPTIONS

Variable	Unit	Description
ASH	percent	Actual ash content
BB	MMtons	Temporary array containing reserves for each mine size for this overburden ratio (surface) reserves for each mine size
BDNLET	percent	Overburden ratio in characters for this seam thickness and mine depth
BRDNC	percent	Overburden ratio distribution by supply region and overburden ratio category
CMTD	MMtons	Committed reserves CMTD(1) - deep CMTD(2) - surface
DEMR	MMtons	Demonstrated reserves DEMR(1) - deep thin DEMR(2) - deep thick DEMR(3) - surface
DEMRD	MMtons	Aggregated demonstrated reserves (AUSM)
DIPLET	100 feet	Mine depth values in characters
DIV	MMtons	Reserves required for single mine
DPSMDT	percent	Deep mine thickness distributions (for deep thick and deep thin mines) by five different reserve thickness ranges
ICOAL	code	EIA coal type
IFLAG	flag	Data flag if IFLAG = 0, then EIA data if IFLAG = 1, then AUSM data
IHHV	code	EIA higher heating value code

Table B1-7 (contd.)

Variable	Unit	Description
INDEX	index	Index into YIELD array for EIA coals
IPAR	flag	Flag for PARMRD; indicates whether global parameters have been read yet from file PARMS
ISTATE	code	EIA supply region code
ISUF	code	Supply region code (12 minus value in codelist K for AUSM categories)
ISULF	code	EIA sulfur category code
ITYPE	flag	Variable used to check to see if the card just read was an end-region or end-coal card
KMARG	percent	Underground reserve seam thickness distribution; same as MDM
LMAX	inches	Maximum seam thickness, used as argument to STHK
LMIN	inches	Minimum seam thickness, used as argument to STHK
LNREG	code	Last supply region (AUSM)
LSTATE	code	Last supply region (EIA)
MDM	percent	Underground and reserve seam thickness distribution; same as KMARG
MOIST	percent	Moisture content, AUSM coals
MYR	years	Mine life (30 years)
NEWMIN	count	Number of new mines
NHHV	code	AUSM higher heating value
NREC	number	Number of EIA parameter records in file PARMS
NREG	code	AUSM supply region
NSUF	code	AUSM sulfur category (12 minus codes in codelist K)
PRODN	MMtons/year	Production

Table B1-7 (contd.)

Variable	Unit	Description
PSURF	fraction	Fraction of reserves in surface mines
PTHICK	fraction	Fraction of reserves in deep thick mines
PTHIN	fraction	Fraction of reserves in deep thin mines
RECFCT	fraction	Reserve fraction surface and deep
RESREQ	fraction	Reserve requirement by mine size and mine type (surface, deep)
SIZEC	percent	Surface mine size distribution by supply region and mine size categories
SMDPC	percent	Deep reserve seam depth distribution by supply region and seam depth distribution
SMTHC	percent	Deep reserve depth distribution
SMTHR	percent	Temporary seam thickness distribution array
SO2LBS	lbs SO_2/MMBtu	Sulfur content for AUSM coals
SZELET	100 MMtons/year	Mine size in characters
SZEMIN	MMtons/year	Surface mine sizes
TEMP	MMtons	Unallocated reserves
THKLET	inches	Seam thickness in characters
TMARG	percent	Deep mine size distribution by depth and seam thickness
T2	MMtons	Reserves array (see Table B1-2)
T3	percent/MMtons	Working array T3(1-7) contains overburden ratio distribution; T3(8-13) contains mine size distribution
T4	inches/feet	Working array T4(1-6) contains seam thickness distribution; T4(7-10) contains depth distribution
XHHV	Btu/lb	Actual higher heating value for AUSM coals

Table B1-7 (contd.)

Variable	Unit	Description
XIDR	fraction	Fraction of deep reserves inaccessible to mining
XISR	fraction	Fraction of surface reserves inaccessible to mining
XX	MMtons	Reserves broken down by overburden ratio (surface) and seam thickness (deep)
YIELD	fraction	Deep yield for all coals in region
YIELDD	fraction	Deep yield for this coal
YIELDS	fraction	Surface yield for this coal
ZZ	MMtons	Reserves broken down by depth and seam thickness (deep)

1.2.1.1 **Surface Reserve Allocation.** There are six steps in the allocation of surface reserves:

1. The surface reserves in stripping ratio category J,(XX) are calculated by multiplying the total surface reserves available for new mining (T2(3)) by the fraction of reserves in the overburden ratio category T3(1-7). T3(1-7) is obtained from file PARMS for each coal type and is based on the minimum and maximum overburden ratios for surface mineable reserves.

$$XX = T3(J) * T2\,(3)/100 \qquad [\text{Eq } 1]$$

2. Within stripping ratio category J, the reserves in surface mine size category M,(BB (M)) are calculated by multiplying the reserves in the stripping ratio category (XX) by the fraction of reserves in the mine size category T3(8-13). T3(8-13) is read from file PARMS for each coal type.

$$BB\,(M) = T3\,(14-M) * XX/100 \qquad [\text{Eq } 2]$$

This calculation assumes that surface mine size categories in SIZEC are in order from the smallest to the largest. The reserves in the vector BB are then the reserves for each mine size in descending order, from the largest mine size to the smallest.

3. Annual production for each mine size, from the largest (M = 1) to the smallest (M = 6), is calculated by first computing reserves for a single mine (DIV):

$$DIV = RESREQ\,(1,M) * YIELDS. \qquad [\text{Eq } 3]$$

Total available reserves are then computed:

$$TEMP = BB\,(M) + TEMP. \qquad [\text{Eq } 4]$$

The value of TEMP is equal to the reserves *not* allocated to the next largest mine size (see Step 4). For the largest mine, TEMP is set equal to the reserves not allocated for the smallest mine in the last stripping ratio category.

The number of mines that can be developed (K) is computed as follows:

$$K = TEMP/DIV. \qquad \text{[Eq 5]}$$

The fractional part of K is dropped, e.g., a value of 2.6 will result in two mines being developed.

Annual production (PRODN) in the mine size category is computed as follows:

$$PRODN = K * SZEMIN\ (1,M) * YIELDS. \qquad \text{[Eq 6]}$$

4. The reserves not allocated to production (TEMP) are then calculated:

$$TEMP = TEMP - K * DIV \qquad \text{[Eq 7]}$$

The value of TEMP is added to the reserves available for the next smallest mine size category.

5. The overburden category (BDNLET (J)), mine size (SZEMIN (1,M)), and production (PRODN) are written to file 20 for later use by RGCOST (see Section 1.4).

6. Steps 1 through 5 are repeated for all stripping ratio categories and mine sizes.

The allocation described above makes several key assumptions. First, it is assumed that reserve blocks that are too small for the development of large mines will be available for development of smaller mines within a stripping ratio category. It is also assumed that reserve blocks too small for the smallest size mine within a stripping ratio category will be allocated to the next largest stripping ratio category. Finally, it is assumed that the distributions of stripping ratios and mine sizes are statistically independent.

1.2.1.2 **Underground Reserve Allocation**. Underground reserve allocation is similar to surface reserve allocation, except that three variables (depth, seam thickness, and mine size) are used rather than two (overburden ratio and mine size). Nine steps are involved in the process of allocating underground reserves:

1. The deep reserves in seam thickness category J are calculated by multiplying the appropriate reserve figure (deep thin and/or deep thick reserves) by the fraction of reserves in the seam thickness category (for reserves using AUSM sulfur categories). Since the breakpoint between deep thin reserves and deep thick reserves is at 42 inches (which is not a breakpoint for the seam thickness categories), the

code is divided into three parts based on seam thickness category. The reserves are computed as follows:

$$\begin{aligned} \textit{If thickness} &= 28'' \quad XX = T4(6) * T2(8) \\ &= 36'' \quad XX = T4(5)\,/T2(8) + T4(4) * T2(6)) \\ &= 48'' \quad XX = (T4(i), j1,3) * T2(6) \end{aligned} \qquad \text{[Eq 8]}$$

where $T2(6)$ = deep thick reserves

$T2(8)$ = deep thin reserves

$T4(1\text{-}6)$ = fraction of reserves in 6 seam thickness categories: 28", 36", 42", 48", 60", 72"

2. Reserves are further broken down into depth categories as follows:

$$ZZ = SMDPR(L4) * XX/10000. \qquad \text{[Eq 9]}$$

where T4(7 → 10) mine depth distribution.

3. The total reserves at depth category L4 and seam thickness category J (22) are assigned to five mine-size categories using the marginal mine-size distribution *TMARG*:

$$BB(M) = TMARG(J,7\text{-}M,L4) * ZZ/100. \qquad \text{[Eq 10]}$$

4. Unallocated reserves are collected by *TEMP*:

$$TEMP = TEMP + BB(M). \qquad \text{[Eq 11]}$$

The value of TEMP is reset to zero before the reserves are assigned to mine sizes within a depth and thickness. Thus, TEMP is equal to zero for the first (largest) mine at each new depth.

5. The reserves assigned to mine-size category M at depth category L4 in seam thickness J are converted to production by computing the reserves required for a single mine (*DIV*),

$$DIV = RESREQ(2,M) * YIELDD; \qquad \text{[Eq 12]}$$

computing the number of mines that can be developed,

$$K = TEMP/DIV; \qquad \text{[Eq 13]}$$

and computing an annual production level,

$$PRODN = K * SZEMIN(M) * YIELDD. \qquad \text{[Eq 14]}$$

6. TEMP is updated to reflect mines that have been allocated to production:

$$TEMP = TEMP - K * DIV. \qquad \text{[Eq 15]}$$

7. Thickness (THKLET(J)), depth (DIPLET(L4)), mine size (SZEMIN(2,M)), and production (PRODN) are written to file 20 for later use by RGCOST.

8. Steps 4 through 7 are repeated for all mine sizes at given values for depth and seam thickness.

9. Steps 1 through 8 are repeated for all mine depths and seam thicknesses.

The assumptions made in allocating underground reserves are similar to the first two assumptions made in allocating surface reserves. First, it is assumed that reserve blocks too small for the development of large mines will be available for the development of smaller mines at the same depth. Second, it is assumed that reserve blocks too small for the smallest mine at a given depth will not be developed.

1.2.1.3 **Resource Allocation Example**. The steps in resource allocation described above are most easily understood by means of an example. The example below shows the resource allocation steps for surface reserves in a single coal type.

Consider a coal type with the following values for surface reserve parameters:

Demonstrated surface reserves: 45,000 million tons

Committed surface reserves: 10,820 million tons

Fraction of illegal-to-mine reserves: 0.15

Recovery factor: 0.90

Clean coal yield: 1.00

Stripping ratio distribution:

5:1	(5 percent)
10:1	(15 percent)
15:1	(20 percent)
20:1	(20 percent)
25:1	(15 percent)
30:1	(15 percent)
45:1	(5 percent)

Surface mine size distribution:

0.2 million tons	(60 percent)
0.5 million tons	(20 percent)
1 million tons	(20 percent).

The total available reserves are computed by subtracting illegal-to-mine reserves and committed reserves:

$$\begin{array}{ccccccc} \textit{Total available} & = & \textit{demonstrated} & - & \textit{illegal-to-mine} & - & \textit{committed} \\ \textit{surface reserves} & & \textit{surface reserves} & & \textit{reserves} & & \textit{reserves} \\ 274.3\,MMton & = & 450.0\,MMton & - & (.15)(450.0\ MMton) & - & 108.20\ MMton \end{array} \qquad [\text{Eq } 16]$$

The available reserves in each mine-size/stripping ratio category are calculated by multiplying the total reserves by the fraction of reserves in each category. For example, the reserves in the 0.2 million ton mine, 10:1 stripping ratio category are 24.687 million tons (274.3 * 0.15 * 0.60). The allocated reserves in each mine-size/stripping ratio in this example are shown in the third column of Table B1-8.

Reserve requirements for each mine size are computed by multiplying the size by the mine life (30 years) and dividing the recovery factor. Reserve requirements are 33.33 million tons for a 1.0 million ton mine (1.0 * 30)/.9), 16.69 million tons for a 0.5 million ton mine, and 6.67 million tons for a 0.2 million ton mine.

Table B1-8

SAMPLE RESOURCE ALLOCATION RESULTS FROM PROGRAM QUANT

(in millions of tons)

Stripping Ratio	Mine Size	Reserves Allocated	Reserves Added	Reserves Developed
05	1.00	2.74	0.0	0.0
05	0.50	2.74	2.74	0.0
05	0.20	8.23	5.49	13.33
10	1.00	8.23	0.38	0.0
10	0.50	8.23	8.61	16.67
10	0.20	24.69	0.17	20.00
15	1.00	10.97	4.86	0.0
15	0.50	10.97	15.83	16.67
15	0.20	32.92	10.14	40.00
20	1.00	10.97	3.05	0.0
20	0.50	10.97	14.03	16.67
20	0.20	32.92	8.33	40.00
25	1.00	8.23	1.25	0.0
25	0.50	8.23	9.48	16.67
25	0.20	24.69	1.04	20.00
30	1.00	8.23	5.72	0.0
30	0.50	8.23	13.95	16.67
30	0.20	24.69	5.52	26.67
45	1.00	5.49	3.54	0.0
45	0.50	5.49	9.02	0.0
45	0.20	16.46	14.51	26.67
Totals		274.30		270.00

The results of allocating reserves to production are shown in the fourth and fifth columns of Table B1-8. Inspection of the first few lines of this table shows how the allocation procedure works. Reserves in the 5:1 stripping ratio are insufficient to support production from 1.0 and 0.5 million ton mines. Consequently, reserves not used for the 1.0 and 0.5 million ton mines (5.49 million tons) are added to the reserves for the 0.2 million ton mine (8.23 million tons), for a total of 13.72 million tons. Two mines, each with 13.33 million tons of reserves, are developed in the 0.2 million ton mine size category. Remaining reserves not developed (0.38 million tons) are added to the reserves for the 1.0 million ton mines in the 10:1 stripping ratio. The procedure then continues for the remainder of the mine-size/stripping ratio categories.

Since QUANT constructs mines in each category only if there are sufficient reserves to meet the reserve requirements, the distribution of reserves actually developed can differ from the distribution input to the model. In the present example, no 1.0 million ton surface mines are developed because none of the blocks assigned to 1.0 million ton mines was large enough to meet the reserve requirement. The difference between calculated and input distribution will generally be large only where the total available reserves are small. When the difference is large, it will have the effect of raising prices since the reserves will be shifted to smaller mines where costs are higher.

1.2.2 Data Handling

QUANT has three input files and one output file. Table B1-9 contains the names of these files and general descriptions of the contents. Table B1-10 provides a detailed description of all the files used by the program. File PARMS is a general file used by both QUANT and RGCOST. This file contains global, regional, and coal-specific mining and costing parameters. The data were originally obtained from an input file to the RAMC program [1].

The RAMC input file was used to make the files MINFRC and PARMS. PARMS contains the mining and costing parameters, and MINFRC contains fractions used to break AUSM reserves into deep thick, deep thin, and surface reserves. The format of these files is described in Table B1-10. The mappings given in Tables B1-3, B1-4, and B1-5 were used to convert EIA regions and categories to AUSM regions and categories.

Table B1-9

PROGRAM QUANT FILES

Input File Name	*Description*
DEMBAS	Demonstrated reserve base, either EIA or AUSM coal type categories, and supply region categories
MINFRC	Mine type fractions for AUSM mines (percentages for deep-thick, deep-thin, and surface mines)
PARMS	Parameter file; includes mining distribution variables for both AUSM and EIA coal types
Output File Name	
MINES	Resultant mines in EIA or AUSM coal types and supply regions

Table B1-10
PROGRAM QUANT: FILE DESCRIPTIONS

Input Files

DEMBAS. Demonstrated reserve base file; contains either EIA or AUSM reserves data, as indicated by the flag in the first column of the first card.

Card	Column	Format	Contents	Unit	Variable Name
1	1	I1	data flag		IFLAG
2	1-10	2F5.2	recovery factors (surface, deep)	fraction	RECFCT
3			blank line		
4			column descriptor		
5			blank line		

The format of the remaining cards depends on the type of data being read.

If IFLAG = 0, then EIA data follows with the following format, one card for each coal:

1-2	A2,1X	EIA supply region code	Table B1-3	ISTATE	
4	A1	EIA higher heating value code	codelist N	IHHV	ICOAL
5	A1	EIA sulfur category code	codelist K	ISULF	
6-15	10.3	deep thick demonstrated reserves	MMtons	DFMR(2)	
16-25	10.3	deep thin demonstrated reserves	MMtons	DEMR(1)	
26-25	10.3	surface demonstrated reserves	MMtons	DEMR(3)	
36-45	10.3	surface committed reserves	MMtons	CMTD(2)	
46-55	10.3	deep committed reserves	MMtons	CMTD(1)	

If IFLAG = 1, then AUSM data follows with the following format, one card for each coal:

1-3	I3	AUSM supply region code	codelist J	NREG
4-6	I3	AUSM sulfur category code	codelist*	NSUF
7-9	I3	AUSM higher heating value code	codelist N	NHHV
10-17	F8.1	reserves	MMtons	DEMPR
18-25	F8.1	sulfur content	lbs SO_2/MMBtu	SO2LBS
26-33	F8.1	percent moisture content	percent	MOIST
34-41	F8.1	percent ash content	percent	ASH
42-49	F8.1	higher heating value	Btu/lb	XHHV
50-59	F10.6	surface committed reserves	MMtons	CMTD(2)
60-69	F10.6	deep committed reserves	MMtons	CMTD(1)

DEMBAS has an end-of-file marker (999 in first 3 columns) for the last record.

* AUSM sulfur codes are 12 minus the codes listed in codelist K.

Table B1-10 (contd.)

MINFRC. Contains the fraction of reserves to be allocated to deep thick, deep thin, and surface mines for all supply regions, sulfur categories, and higher heating values. Sorted by supply region, sulfur category code, and higher heating value code. The following lists the format for one supply region.

Card	Column	Format	Contents	Unit	Variable Name
1	10-12	I3	AUSM supply region	codelist J	
2-34	8-9	I2	sulfur category	*	
	10-11	I2	higher heating value category	codelist N	
	12-18	F7.4.1X	fraction thick reserves		PTHICK
	20-26	F7.4.1X	fraction thin reserves		PTHIN
	28-34	F7.4.1X	fraction surface reserves		PSURF

* AUSM sulfur codes are 12 minus the codes listed in codelist K.

Table B1-10 (contd.)

PARMS. Contains all the parameters needed for QUANT and RGCOST. Variables in this file are specific to the reserve base being used. For ease of handling, the AUSM parameters were concatenated to the bottom of the EIA parameters. The first seven records of file PARMS contain global parameters and the number of records in the EIA parameter file. The global variable records are described first; the individual descriptions of the EIA and AUSM parameters follow.

The first seven records on file PARMS are as follows:

Card	Column	Format	Content	Unit	Variable Name
1	1	I5	number of EIA parameter records	number	NREC
2	1-4	F4.2	payroll overhead (percent of direct labor)	fraction	PAYOUR
3	1-4	F4.2	indirect labor (percent of direct labor)	fraction	XDRLAB
4	1-12	3F4.2	abandoned mine tax	$/ton/year	AMR
5	1-12	3F4.2	black lung tax	$/ton/year	BLUNG
6	1-8	2I4	mine life	years	L
7	1-4	F4.2	indirect cost of supplies (percent of power and supplies cost)	fraction	ADDPS

The regional parameters for EIA data are as follows:

Card	Column	Format	Contents	Unit	Variable Name
1	16-17	A2	EIA supply region		PSTATE
2	1-70	14(F4.2,1X)	reclamation costs	$/ton	RECL
3	11-20	F10.4	license fee per ton of clean coal	$/clean ton	XLIC
	31-40	F10.4	royalty fee per clean ton of coal	$/clean ton	ROY
4	11-20	F10.4	federal royalty for surface mines	$	FEDS
	31-40	F10.4	federal royalty for deep mines	$	FEDD
5	11-20	F10.4	surface exposure insurance per $100 of payroll	$	XINSS
	31-40	F10.4	deep exposure insurance per $100 of payroll	$	XINSD
6	11-20	F10.4	surface union welfare cost	$/clean ton	SWEL
	31-40	F10.4	deep union welfare cost	$/clean ton	DWEL
7	11-20	F10.4	surface union welfare cost	$/man-day	SWELD
	31-40	F10.4	deep union welfare cost	$/man-day	DWELD
8	11-20	F10.4	severance tax	$	SEVT
	31-40	F10.4	severance tax	$/clean ton	SVTSR
9	11-20	F10.4	surface labor rate	$/man-day	DWS
	31-40	F10.4	deep labor rate	$/man-day	DWD
10	5-64	20I3	deep reserve seam thickness distribution		MDM
11	5-9	F5.2	fraction of deep reserves that are inaccessible	fraction	XIDR
12	5-9	F5.2	fraction of surface reserves that are inaccessible	fraction	XISR

Table B1-10 (contd.)

These regional parameters are followed by the coal-specific parameters (yields, cleaning costs, and mining distributions). There are records only for coals for which there are reserves in the EIA portion of this file. The format of the coal-specific records is as follows:

Card	Column	Format	Contents	Unit	Variable Name
1	16	A1	EIA higher heating value code	codelist N	
1	17	A1	EIA sulfur category code	codelist K	
2	11-20	F10.4	surface yield	percent	YIELDS
	31-40	F10.4	deep yield	percent	YIELDD
3	11-20	F10.4	fixed cleaning costs	$/ton	FIXCLN
	31-40	F10.4	variable cleaning costs	$/ton	VARCLN
4	11-66	7F8.3	overburden ratio distribution	percent	BRDNC
5	11-42	4F8.3	seam depth distribution	percent	SMDPC
6	11-58	6F8.3	seam thickness distribution	percent	SMTHG
7	11-58	6F8.3	mine size distribution	percent	SIZEC

After all the coals are listed for a given region, an end region card, labeled as such, is produced. It has an "E" in the first column.

Following the EIA parameters are the AUSM parameters. The format is similar to the format used for EIA parameters and is outlined below. After all the coals are listed for a given region, an end region card with nines in the first five columns appears.

The regional parameters for AUSM data are as follows:

Card	Column	Format	Contents	Unit	Variable Name
1	16-17	I2	AUSM supply region	-	PSTATE
2	1-70	14(F4.2,1X)	reclamation costs	$/ton	RECL
3	11-20	F10.4	license fee per ton of clean coal	$/clean ton	XLIC
	31-40	F10.4	royalty fee per clean ton of coal	$/clean ton	ROY
4	11-20	F10.4	federal royalty for surface mines	$	FEDS
	31-40	F10.4	federal royalty for deep mines	$	FEDD
5	11-20	F10.4	surface exposure insurance per $100 of payroll	$	XINSS
	31-40	F10.4	deep exposure insurance per $100 of payroll	$	XINSD
6	11-20	F10.4	surface union welfare cost	$/clean ton	SWEL
	31-40	F10.4	deep union welfare cost	$/clean ton	DWEL
7	11-20	F10.4	surface union welfare cost	$/clean ton	SWELD
	31-40	F10.4	deep union welfare cost	$/clean ton	DWELD
8	11-20	F10.4	severance tax	$	SEVT
	31-40	F10.4	severance tax	$/clean ton	SVTSR
9	11-20	F10.4	surface labor rate	$/man-day	DWS
	31-40	F10.4	deep labor rate	$/man-day	DWD
10	5-64	20I3	deep reserve seam thickness distribution		MDM

Table B1-10 (contd.)

11	5-9	F5.2	fraction of deep reserves that are inaccessible	fraction	XIDR
12	5-9	F5.2	fraction of surface reserves that are inaccessible	fraction	XISR

These regional parameters are followed by the coal-specific parameters (yields and cleaning costs). There are records only for coals for which there are reserves in the AUSM reserve data file. The format of the coal-specific records is as follows:

Card	Column	Format	Contents	Unit	Variable Name
1	18-19	I2,3X	AUSM sulfur category code	*	ISUF
	23	I1	AUSM higher heating value code	codelist N	IHHV
2	11-20	F10.4	surface yield	percent	YIELDS
	31-40	F10.4	deep yield	percent	YIELDD
3	11-20	F.0.4	fixed cleaning costs	$/ton	FIXCLN
	31-40	F10.4	variable cleaning costs	$/ton	VARCLN
4	11-66	7F8.3	overburden ratio distribution	percent	BRDNC
5	11-42	4F8.3	seam depth distribution	percent	SMDPC
6	11-58	6F8.3	seam thickness distribution	percent	SMTHC
7	11-58	6F8.3	mine size distribution	percent	SIZEC

* AUSM sulfur codes are 12 minus the codes listed in codelist K.

The AUSM portion of the file is sorted by supply region and sulfur code.

Table B1-10 (contd.)

Output Files

MINES. There is one record for each mine generated by QUANT. They are sorted in the same manner as the input file DEMBAS. Because the formats for EIA mines and AUSM mines are slightly different, they are listed separately. Records for surface mines and deep mines are slightly different. Surface mine records report the overburden ratio, whereas deep mine records report the seam thickness and mine depth. The two record types are shown below for both EIA and AUSM mines. The first record of MINES has a 0 or 1 in the first column indicating whether EIA or AUSM mines follow.

Record Type	Column	Format	Contents	Unit/ Codelist	Variable Name
EIA-surface	1-2	A2	EIA supply region code	Table B1-3	ISTATE
	3	A1	EIA higher heating value code	codelist N	
	4	A1	EIA sulfur category code	codelist K	IHHV
	5	'S'		percent	ISULF
	6-7	A2,2X	overburden ratio		BDNLET
	10-11	A2,1X	mine size		SZELET
	13-22	F10.2	production		PRODN
EIA-deep	1-2	A2	EIA supply region code	Table B1-3	ISTATE
	3	A1	EIA HHV code	codelist N	IHHV
	4	A1	EIA sulfur category code	codelist K	ISULF
	5	'D'			
	6-7	A2	seam thickness	inches	THKLET
	8-9	A2	seam depth	hundred feet	DIPLET
	10-11	A2,1X	mine size	10^5 tons	SZELET
	13-22	F10.2	production	MMtons	PRODN
AUSM-surface	1-2	I2	AUSM supply region code	codelist J	NREG
	3-4	I2	AUSM sulfur category code	*	NSUF
	5	I1	AUSM higher heating value code	codelist N	NHHV
	6	'S'			
	7-8	A2,2X	overburden ratio	percent	BDNLET
	11-12	A2	mine size	10^5 tons	SZELET
	13-22	F10.2	production	MMtons	PRODN
	23-30	F8.1	actual sulfur content	lbs SO_2/MMBtu	SO2LBS
	31-38	F8.1	moisture content	percent	MOIST
	39-46	F8.1	ash content	percent	ASH
	47-54	F8.1	actual higher heating value	Btu/lb	XHHV

* Sulfur codes are 12 minus the codes listed in codelist K

Record Type	Column	Format	Contents	Unit/ Codelist	Variable Name
AUSM-deep	1-2	I2	AUSM supply region code	codelist J	NREG
	3-4	I2	AUSM sulfur category code	*	NSUF
	5	I1	AUSM higher heating value code	codelist N	NHHV
	6	'D'			
	7-8	A2	seam thickness	inches	THKLET
	9-10	A2	seam depth	hundred feet	DIPLET
	11-12	A2	mine size	10^5 tons	SZELET

Table B1-10 (contd.)

Record Type	Column	Format	Contents	Unit/ Codelist	Variable Name
	13-22	F10.2	production	MMtons	PRODN
	23-30	F8.1	actual sulfur content	lbs SO_2/MMBtu	SO2LBS
	31-38	F8.1	moisture content	percent	MOIST
	39-46	F8.1	ash content	percent	ASH
	47-54	F8.1	actual higher heating value	Btu/lb	XHHV

* Sulfur codes are 12 minus the codes listed in codelist K.

1.2.3 Subroutine Descriptions

QUANT has three subroutines: PARMRD, SUFCON, and STHK. PARMRD reads the parameter file; SUFCON is used to convert EIA sulfur codes into numbers; and STHK is used to develop distribution arrays. An additional subroutine OBDN that is not used by QUANT is included here. OBDN was used when the file PARMS was made. A description of each one follows.

1.2.3.1 Subroutine PARMRD

Subroutine:	PARMRD.
Called by:	QUANT.
Calls:	SUFCON.
Arguments:	IFLAG, IPAR.
Task:	PARMRD reads all the parameters associated with the next region in the file. This includes regional and coal-specific parameters.
Method:	The first time PARMRD is called (IPAR = 0) the number of EIA records in the file PARMS is read. Then if AUSM parameters are requested (IFLAG = 1) the EIA parameter records are skipped. On subsequent calls (IPAR ≠ 0) the next region's parameters are to be read.

The parameters of only one supply region are read on each call to PARMRD. The values are read according to the file layout of file PARMS given in Table B1-10. If AUSM parameters are read, then file MINFRC is also read, one region at a time. Subroutine SUFCON is used to convert EIA sulfur and higher heating value categories into an integer index. This index is then used in arrays that are EIA coal type-specific.

In addition to reading the variables from files PARMS and MINFRC, PARMRD initializes the variables KMARG and TMARG.

1.2.3.2 Subroutine SUFCON

Called by: PARMRD, QUANT.

Calls: None.

Arguments: ISULF, IHHV, INDEX.

Task: Converts EIA sulfur and higher heating codes into an index between 1 and 40. This index is used in arrays which are coal type-specific.

Method: The sulfur category letters are converted to numbers from 1 to 8. The higher heating value category letters are converted to numbers from 0 to 4. An index is set equal to eight times the higher heating value plus the sulfur number. This yields a number from 1 to 40 for use as an index into coal-specific arrays.

1.2.3.3 Subroutine STHK

Called by: QUANT.

Calls: None.

Arguments: ARY, LMIN, LMAX.

Task: Given minimum and maximum seam thicknesses for deep mineable reserves, assigns percentage distribution of reserves to seam thickness categories using even distribution.

If the minimum thickness is less than 42 inches, the minimum for thick reserves is assumed to be 42 inches. If the minimum and maximum are zero, or the minimum is greater or equal to the maximum, the percentage assigned is zero. Thin reserves are always assigned 57.1 percent to 28- to 36-inch seam thicknesses and 42.9 percent to 36- to 42-inch seam thickness.

1.2.3.4 Subroutine OBDN

Called by: PARMRD.

Calls: None.

Arguments: ARY, LMIN, LMAX.

Task: Given minimum and maximum overburden ratios for surface mineable reserves, assigns percentage distribution of reserves to overburden ratio categories from 5:1 to 45:1. Even distribution is used between limits set by LMIN and LMAX, with steps of 5 from 5 to 30 and of 15 from 30 to 45. If the minimum and maximum are zero, or the minimum is greater than or equal to the maximum, the percentage is given the value zero. If the maximum overburden ratio is greater than 45:1, a recovery factor is calculated ((45-LMIN)/(LMAX-LMIN)), with LMAX set at 45. This recovery factor is used to calculate the percentages of distribution ratios.

1.2.4 Flowchart of QUANT

Figure B1-2 is a flowchart of the main program QUANT.

1.2.5 Variable Definitions

Tables B1-6 and B1-7 summarize the variables used in QUANT.

1.3 Model Mine Costs (Program MNCOST)

Program MNCOST calculates four components of the minemouth cost of coal: initial capital, deferred capital, labor (productivity), and power and supplies. These region-dependent cost values, which are inputs to RGCOST (see Section 1.4), are expressed as functions of the four mine characteristics: mine size S, seam thickness T, and seam depth D or overburden ratio R. The cost equations are taken directly from the program in RAMC [1] where the nine types of "model mines" defined in the EIA Annual Report to Congress [6] are characterized.

The equations for the four cost components depend only on the model mine equations and therefore are not scenario dependent. (Scenario-dependent inputs are handled in RGCOST.) The four components need to be calculated only once for each set of surface and deep mines. MNCOST is run only when the mine costing equations or the definitions of S,T,D,R are changed.

The outputs of MNCOST are:

ICAP (S,D,R): initial capital cost (1980 dollars)

DCAP (S,D,R): undiscounted sum of real deferred capital costs (1980 dollars)

TPMD (S,D,R): labor productivity (tons per man-day)

PS (S,D,R): annual cost for supplies, water, and power (1980 dollars)

1.3.1 Central Algorithms and Basic Assumptions

The model mine equations used for EIA/ARC81 are straightforward. The cost equations for ICAP and DCAP for deep mines are written in the form

$$A = a + b * SIZE + c * DEPTH + e * DEPTH * SIZE \qquad \text{[Eq 17]}$$

where the values of a, b, c, and e are as in in Table B1-11. ICAP and DCAP equations for surface mines are of the form

$$A = a + b * SIZE^{e} + c * OVR * SIZE \qquad \text{[Eq 18]}$$

where the values of a, b, e, and c are as in Table B1-12.

The equations for TPMD and PS are also simple in form. The equations for deep mines are as follows:

$$TPMD = \frac{BSRATE * c * SIZE}{d(a * SIZE + b * DEPTH * SIZE)} \qquad \text{[Eq 19]}$$

$$PS = \frac{(a * SIZE + b * DEPTH * SIZE) * e}{c} \qquad \text{[Eq 20]}$$

Table B1-11
COST VALUES FOR DEEP MINES

	ICAP				DCAP			
	a	b	c	e	a	b	c	e
Southern Appalachia	.55	35.48	.0104	0	0	18.72	0	0
Northern Appalachia	1.08	43.56	.0104	0	0	14.08	0	0
Middle West	1.73	41.60	.0104	0	0	13.80	0	0
Far West	1.61	34.37	.0104	0	0	12.2	0	0

Note: ICAP is the initial capital cost. DCAP is the undiscounted sum of real deferred capital costs. Both are in 1980 dollars. ICAP and DCAP equations for deep mines are written in the form A = a + b * SIZE + c * DEPTH + e * DEPTH * SIZE, where the values of a, b, c, and e are dependent on region.

Source: Reference 1.

Table B1-12
COST VALUES FOR SURFACE MINES

	ICAP				DCAP			
	a	b	c	e	a	b	c	e
Central Appalachia	0	2.815	2.365	.419	0	2.318	1.947	.419
Northern Appalachia	2.03	0	3.949	0	3.239	0	1.848	0
Middle West	0	2.713	2.671	.436	0	15.32	.1637	.436
Far West	0	3.259	4.391	1	0	8.268	.1712	.577
Campbell County	0	1.934	11.943	1	0	4.552	3.19	1

Note: ICAP is the initial capital cost. DCAP is the undiscounted sum of real deferred capital costs. Both are in 1980 dollars. ICAP and DCAP equations for surface mines are written in the form A = a + c * OVR * SIZE + b * SIZE* * e, where the values of a, b, c, and e are dependent on region.

Source: Reference 1.

where the values of a, b, c, d, e, and $BSRATE$ are as in Table B1-13. BSRATE is the labor rate (in 1980 dollars per man-day).

The equations for TPMD and PS for surface mines are as follows:

$$TPMD = \frac{BSRATE * SIZE * e}{(a + b * SIZE^{d} + c * OVR * SIZE) * f} \quad \text{[Eq 21]}$$

$$PS = \frac{g(a + b * SIZE^{d} + c * OVR * SIZE)}{e} \quad \text{[Eq 22]}$$

where the values for a, b, c, d, e, f, g, and $BSRATE$ are as in Table B1-14.

Campbell County surface mine overburden ratios average 0.5, but the smallest overburden ratio in this model is 5.0. Therefore, for Campbell County surface mines the overburden ratio was modified to equal (OVR * .15 + 1.425). This is how the RAMC [1] handled this problem.

These equations are embedded in a simple loop through all viable combinations of supply region, mine type, mine size, overburden ratio, and mine depth. Program MNCOST is outlined in Figure B1-3.

1.3.2 Data Handling

An outline of the MNCOST output file is given in Table B1-15. Variable information and variable descriptions are found in Tables B1-16 and B1-17, respectively.

1.3.3 Flowchart of MNCOST

The flowchart of MNCOST is in Figure B1-3.

1.3.4 Variable Definitions

Tables B1-16 and B1-17 summarize the variables in MNCOST.

1.4 Minemouth Cost (Program RGCOST)

RGCOST determines a minimum minemouth selling price for each region, time period, and coal type. The minimum selling price is assumed to equal the sum of the four regionally dependent components of the cost of mining coal, which are computed in MNCOST. Before summation, these

Table B1-13

PRODUCTIVITY VALUES AND SUPPLY, WATER, AND POWER VALUES FOR DEEP MINES

	a	b	c	d	e	BSRATE
Southern Appalachia	26.68	.001	6.666	2.168	1.226	107.66
Northern Appalachia	25.12	.001	12.811	4.231	2.087	89.84
Middle West	20.83	.001	21.428	6.612	4.010	100.17
Far West	19.78	.001	19.777	6.44	3.191	93.77

Note: TPMD is labor productivity (in tons per man-day). PS is the annual cost for supplies, water, and power (in 1980 dollars). BSRATE is the labor rate (in 1980 dollars per man-day) used in model mine costs.

$$\text{TPMD} = \frac{\text{BSRATE*c*SIZE}}{\text{d(a*SIZE+b*DEPTH*SIZE)}}$$

$$\text{PS} = \frac{\text{e(a*SIZE+b*DEPTH*SIZE)*e)}}{\text{c}}$$

The values of a, b, c, d, e, and BSRATE are dependent on region.

Source: Reference 1.

Table B1-14
PRODUCTIVITY VALUES AND SUPPLY, WATER, AND POWER VALUES FOR SURFACE MINES

	a	b	c	d	e	f	g	BSRATE
Central Appalachia	0	1.549	1.945	.419	2.924	.252	1.359	98.61
Northern Appalachia	4.143	0	0	0	4.143	.973	1.686	57.24
Middle West	5.607	6.406	0	.256	11.228	1.877	2.677	123.28
Far West	9.262	4.555	0	1	22.926	1.986	5.564	112.73
Campbell County[a]	0	3.058	6.967	1	32.709	3.56	4.005	109.12

[a] The average overburden ratios of surface mines in Campbell County are less than the minimum overburden ratio handled by the minemouth cost preprocessor. Therefore, for mine costing region Campbell County the overburden scale is replaced by (OVR * .015 + 1.425).

Note: TPMD is labor productivity (in tons per man-day). PS is the annual cost for supplies, water, and power (in 1980 dollars). BSRATE is the labor rate (in 1980 dollars per man-day) used in model mine costs.

$$\mathrm{TPMD} = \frac{\mathrm{BSRATE} * \mathrm{SIZE} * e}{(a + b * \mathrm{SIZE}^{d} + c * \mathrm{OVR} * \mathrm{SIZE}) * f}$$

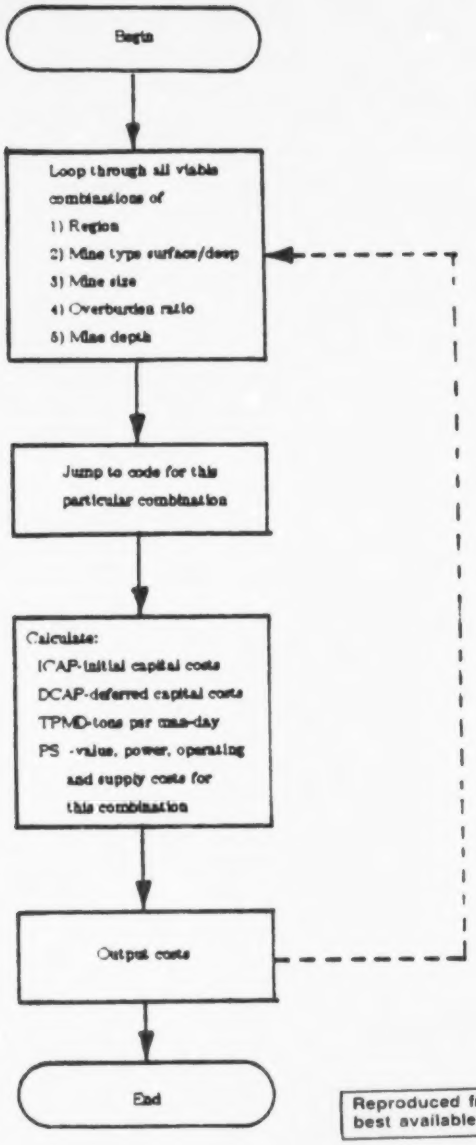
$$\mathrm{PS} = \frac{g(a + b * \mathrm{SIZE}^{d} + c * \mathrm{OVR} * \mathrm{SIZE})}{e}$$

The values of a, b, c, d, e, f, g, and BSRATE are dependent on region.

Source: Reference 1.

Figure B1-3

PROGRAM MNCOST FLOWCHART


Begin
Loop through all viable combinations of
1) Region
2) Mine type surface/deep
3) Mine size
4) Overburden ratio
5) Mine depth
Jump to code for this particular combination
Calculate:
ICAP-initial capital costs
DCAP-deferred capital costs
TPMD-tons per man-day
PS -value, power, operating and supply costs for this combination
Output costs
End

Reproduced from best available copy.

Table B1-15

MNCOST OUTPUT FILE (MMAT)

Column	Format	Contents	Unit	Variable Name
1	I1	cost region	Codelist J[a]	IREG
3	A1	mine type (S = surface; D = deep)	letter	TYP
4-7	F4.1	mine size	MMtons/year	SIZE
9-12	F4.1	overburden ratio	percent	OVR
14-17	F4.1	mine depth	feet	DEPTH
19-28	F10.5	initial capital cost	1980$	ICAP
30-39	F10.5	undiscounted sum of real deferred capital costs	1980$	DCAP
41-50	F10.5	labor productivity	tons/man-day	TPMD
52-61	F10.5	water, power, and operating supply costs	1980$	PS

[a] Codelist J [7] is for AUSM regions.

Note: The MNCOST output file gives model mine costs by supply region, mine type (surface, deep), mine size, overburden ratio, and mine depth. There is a record for all meaningful combinations of these specifications. This file is sorted by region, mine type, mine size, overburden ratio, and mine depth. Not all combinations are represented because not all of them are meaningful.

Table B1-16

PROGRAM MNCOST: VARIABLE INFORMATION

Variable	Type	Dimension	Unit	Accessed by
BSCOST	real	1	ratio	MNCOST
BSLABR	real	1	1980$	MNCOST
BSRATE	real	1	$/man-day	MNCOST
DCAP	real	1	1980$	MNCOST
DEPTH	real	1	feet	MNCOST
ICAP	real	1	1980$	MNCOST
IDEEP	integer	1	index	MNCOST
IOVR	integer	1	index	MNCOST
IREG	integer	1	code	MNCOST
ISZE	integer	1	index	MNCOST
ITYP	integer	1	code	MNCOST
LDEEP	integer	1	index	MNCOST
LOVR	integer	1	index	MNCOST
OVR	integer	1	ratio	MNCOST
PDEPTH	real	4	hundred feet	MNCOST
POVR	real	7	ratio	MNCOST
PS	real	1	1980$	MNCOST
PSIZE	real	6	MMtons/year	MNCOST
SIZE	real	1	MMtons/year	MNCOST
TPMD	real	1	MMtons/man-day	MNCOST
TYP	real	1	code	MNCOST

Table B1-17

PROGRAM MNCOST: VARIABLE DESCRIPTIONS

Variable	Unit	Description
BSCOST	ratio	Total annual operating cost estimating equation/ Total annual operating cost of base mine
BSLABR	1980$	Annual direct labor cost estimating equation
BSRATE	$/man-day	Labor rate (1980$/man-day)
DCAP	1980$	Deferred capital cost
DEPTH	feet	Mine depth
ICAP	1980$	Initial capital cost
IDEEP	index	Index into deep array
IOVR	index	Index into mine depth array PDEPTH
IREG	code	Model mine costing region
ISZE	index	Index into mine size array PSIZE
ITYP	code	Model mine type (surface or deep)
LDEEP	index	Index into mine depth array PDEPTH
LOVR	index	Index into overburden ratio array POVR
OVR	ratio	Overburden ratio
PDEPTH	hundred feet	Array containing mine depths
POVR	ratio	Array containing overburden ratios
PS	1980$	Power and supplies costs
PSIZE	MMtons/year	Array containing mine sizes
SIZE	MMtons/year	Mine size
TPMD	MMtons/man-day	Productivity (tons per man day)
TYP	code	Mine type (S=Surface, D=Deep)

components are adjusted to reflect scenario-dependent variables such as inflation rate, interest, return on equity, real escalation rates, reclamation costs, and insurance costs. Figure B1-4 is a flowchart of the RGCOST program. Table B1-18 lists the default values for scenario and exogenous variables used in RGCOST.

For each supply region and coal type, the present value of the minemouth cost for the life of the mine is calculated for each of the mines obtained from the output of QUANT. The mine with lowest present value is reported. The minemouth cost of the coal from this mine is calculated for each of the time periods. This cost is calculated by leveling the present value, escalating each component of the 1980 cost, and then summing.

1.4.1 Central Algorithms and Basic Assumptions

RGCOST calculates the present value of the minemouth cost for each of the mines reported from QUANT. The mine with the lowest present value price is the mine from which RGCOST calculates the minemouth cost for each of the reported years. The average cost per ton in 1980 dollars reported by RGCOST, in constant 1980 dollars, is the sum of after-tax capital costs (leveled in real terms) plus operating costs. Table B1-18 describes the scenario variables and lists default values used in the program. Tables B1-19 and B1-20 list variable descriptions and variable information for all variables used in RGCOST.

The following discussion explains the equations used for calculating the present value cost and current cost equations. Input variables are indicated as "data"; variables embedded in the routine are indicated as "hard wired."

The present value (including tax) of opening a mine in 1980 and operating it for L years, expressed in 1980 dollars per ton, is

$$PV = \frac{A(PRE + PP) + B(PRD + PL + PPS + PO) + C(PDPR)}{(YIELD * SIZE * LIFE)} \qquad [\text{Eq } 23]$$

where PV = present value of a ton of coal (1980\$/ton)

PRE = present value of return to equity (1980\$)

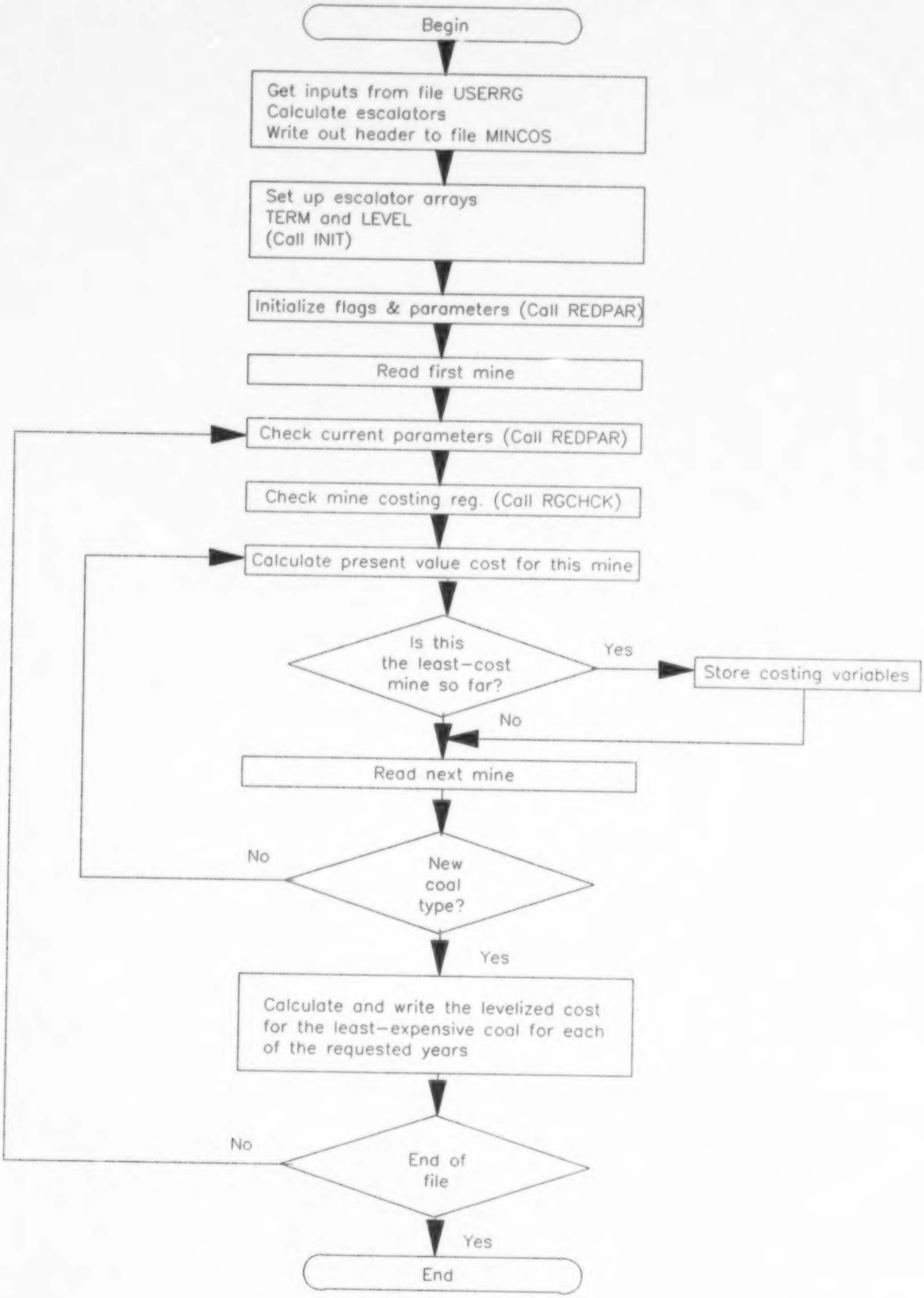


Figure B1-4
PROGRAM RGCOST FLOWCHART

Begin
Get inputs from file USERRG
Calculate escalators
Write out header to file MINCOS
Set up escalator arrays
TERM and LEVEL
(Call INIT)
Initialize flags & parameters (Call REDPAR)
Read first mine
Check current parameters (Call REDPAR)
Check mine costing req. (Call RGCHCK)
Calculate present value cost for this mine
Is this the least-cost mine so far?
Yes
Store costing variables
No
Read next mine
No
New coal type?
Yes
Calculate and write the levelized cost for the least-expensive coal for each of the requested years
No
End of file
Yes
End

Table B1-18
PROGRAM RGCOST: DEFAULT VALUES FOR PARAMETERS AND SCENARIO VARIABLES

Description	Default Value	Variable Name
User-Specified Financial Parameters		
Inflation	.06	XFLAT
Real escalation of capital	0	CAPESK
Real escalation of labor	.01	EL
Real escalation of power and supplies	0	EPS
Real escalation of other costs	0	EO
Corporate tax rate	.5	TAX
Real after-tax rate of return on equity	.061	RE
Real rate of cost of debt	.015	RD
Debt ratio	.30	D
Physical Parameters		
EIA beneficiation yield by region and coal type	a	YIELD
Life of a mine - surface (years)	30	L(1)
- deep (years)	30	L(2)
Additional Capital		
Fixed reclamation costs by region ($/ton/yr)	a	RECL(1)
License fees ($/ton/yr)	.10	XLIC
Additional Power and Supplies		
Indirect cost of supplies (percent of PS)	15	ADDPS
Labor		LAB
Wage rate by region - surface ($/man-day)	a	DWS
- deep ($/man-day)	a	DWD
Additional Labor		
Payroll overhead (percent of direct labor)	20	PAYOUR
Indirect labor (percent of direct labor)	15	XDRLAB
Variable reclamation costs by region ($/ton/yr)	a	RECL(2)
EIA variable beneficiation cost by coal type and region	a	CLEAN(2)
Exposure insurance by region (percent of direct labor)		
- surface	a	XINSS
- deep	a	XINSD
Union welfare $/man-day - surface ($/man-day)	4.12[b]	SWELD
- deep ($/man-day)	4.12[b]	DWELD
+		
Union welfare $/clean ton - surface ($/clean ton)	2.19[b]	SWEL
- deep ($/clean ton)	2.19[b]	DWEL
Other Nonescalating Costs		ON
EIA fixed (annualized) beneficiation cost by coal type and region	a	CLEAN(1)

Table B1-18 (contd.)

Description	Default Value	Variable Name
Black lung tax - surface ($/ton/yr)	.50	BLUNG(1)
- deep ($/ton/yr)	.25	BLUNG(2)
- lignite ($/ton/year)	0	BLUNG(3)
Royalty by region	a	ROY
Abandoned Mine Tax - surface ($/ton/yr)	.35	ABDM(1)
- deep ($/ton/yr)	.15	ABDM(2)
- lignite ($/ton/yr)	.25	ABDM(3)

[a] Regional and/or coal-specific values.

[b] Defaults when regional values not specified.

Source: Reference 6.

Table B1-19

PROGRAM RGCOST: VARIABLE DESCRIPTIONS

Variable	Unit	Description
A	fraction	Coefficient in present value of costs (depends upon tax case)
ABDM	\$/ton/year	Abandoned mine tax
ACAPES	fraction	$(1+\text{CAPESK})^i$ for i=1, 65 capital escalator array
ADDCAP	\$/clean ton	First year annualized fixed cost of reclamation and licenses
ADDLAB	\$/year	Additional labor costs
ADDPS	fraction	additional power and supplies, fraction of PS
AEL	fraction	$(1+\text{EL})^i$ for i=1, 65 labor escalator array
AEO	fraction	$(1+\text{EO})^i$ for i=1, 65 other cost escalator array
AEPS	fraction	$(1+\text{EPS})^i$ for i=1, 65 power and supplies escalator array
AMR	\$/clean ton	Abandoned mine tax
ARO	fraction	$(1+\text{RO})^i$ for i=1, 30 real escalator array
ASH	percent	Ash content of current coal
AXFLAT	fraction	$(1+\text{XFLAT})^i$ for i=1, 65 inflation escalator array
B	fraction	Coefficient in present value calculation (depends upon tax case)
BLACK	1980\$/ton	Black lung tax current value
BLUNG	1980\$/ton	Black lung tax for surface, deep, and lignite mines
C	fraction	Coefficient in present value calculation (depends upon tax case)
CAPESK	percent	Capital escalator (user specified)
CDPR	1980\$	Levelized depreciation allowance
CL	1980\$	Levelized labor-related costs
CLEAN	\$/clean-ton	Cleaning cost (fixed and variable)
CO	1980\$	Levelized cost of other costs

Table B1-19 (contd.)

Variable	Unit	Description
COST	cents/MMBtu	Cost of least expensive coal
CP	1980$	Levelized retirement of principal
CPS	1980$	Levelized cost of power and supplies
CRD	1980$	Levelized return on debt
CRE	1980$	Levelized return on equity
D	percent	User-specified debt ratio
DCAP	1980$	Deferred capital in 1980$
DDCAP	1980$	Deep deferred capital by mine size
DEEP	feet	Vector of all possible mine depths
DEP		Stores all deep mine costing variables by region, mine size, and mine depth
DEPR	1980	Depreciation
DEPTHM	feet	Mine depth
DICAP	1980$	Deep initial capital by mine size and depth
DPSUP	1980$	Deep power and supplies by size and mine depth
DPT	$/ton	1980$ per ton of coal
DTPMD	tons/man-day	Deep TPMD by mine size and depth
DWD	$/man-day	Deep labor rate
DWEL	$/clean-ton	Deep union welfare
DWELD	$/man-day	Deep union welfare
DWS	$/man-day	Surface labor rate
EL	fraction	Real escalation of labor (user specified)
ELSUM	fraction	$\text{ELSUM(i)} = \sum_{j=1}^{LIFE} \frac{(1 + EL)^j}{(1 + RO)^j}$
EO	fraction	Real escalation of other costs (user specified)

Table B1-19 (contd.)

Variable	Unit	Description
EOSUM	fraction	EOSUM(i) $= \sum_{j=1}^{LIFE} \frac{(1+EO)^j}{(1+RO)^j}$
EPS	fraction	Real escalation of power and supplies (user specified)
EPSUM	fraction	EPSUM(i) $= \sum_{j=1}^{LIFE} \frac{(1+\ EPS)^j}{(1+\ RO)^j)}$
F	fraction	1 - SEVT-FEDTAX
FEDD	$/ton	Federal royalty for deep mines
FEDS	$/ton	Federal royalty for surface mines
FEDTAX	fraction	= feds if surface mine, = fedd if deep mine
FIXCLN	$/clean ton	Fixed cleaning costs
GNPINF	fraction	Factor that converts 1975 to AUSM model year (1980) (user specified)
IBASYR	year	Assumed to be 1980
ICAP	1980$	Initial capital cost in 1980$
ICOAL	code	Coal type
ICODE	code	EIA coal type index into arrays
IDATA	flag	Data flag; 0 => EIA, 1 => AUSM data
IDEEP	code	Mine depth code
IEND	flag	End of data flag
IHHV	code	higher heating value code
IOVR	code	Overburden ratio code
IPAR	flag	Indicates whether this is the first call to REDPAR
IREG	code	Vector of all supply region codes by cost regions
IREGN	code	Current cost region
ISIZE	code	Mine size code

Table B1-19 (contd.)

Variable	Unit	Description
ISUF	code	Sulfur code (if AUSM the value is 12 minus that listed in codelist K)
ITYPE	letter	S = surface, D = deep for currently cheapest coal
IYR	year	Years that costs were requested (user specified)
JDEEP	index	Index into DEEP array, index for current mine
JOVR	index	Index into OVER array, index for current mine
JSIZE	index	Index into SIZE array, index for current mine
K	1980$	Stream of capital investments
L	years	Mine life L(1) = surface mine life, L(2) = deep mine life
LAB	$/year	Regional adjusted labor cost
LCOAL	code	Coded sulfur category for last coal
LEVEL	fraction	Levelization factor = $\frac{RO(1 + RO)^{30}}{(1 + RO)^{30}-1}$
LHHV	code	Coded HHV category for last coal
LIFE	year	Current mine life
LSTATE	code	Coded region for last coal
LSUF	code	Sulfur code of last coal (if AUSM the value is 12 minus that in codelist K)
L1	years in future	First 25 percent of mine life (L)
L2	years in future	Next 50 percent of mine life (L) after L1
MOIST	percent	Percent moisture of current coal
NREC	counter	Number of EIA parameter records in file PARMS
NYR	counter	Number of years specified for costs (user specified)
ON	1980$	Other 1980 non-escalating regional cost
OVER	fraction	Vector of all possible over burden ratios

Table B1-19 (contd.)

Variable	Unit	Description
OVRM	code	Overburden ratio code
PAYOVR	percent	Payroll overhead (percent of direct labor)
PDEPTH	code	Depth of currently least expensive mine
PDPR	1980$	Present value of depreciation of capital
PL	1980$	Present value of labor-related cost
PO	1980$	Present value of other non-escalating costs
POVR	fraction/inches	Overburden ratio/seam thickness of currently least expensive mine
PP	1980$	Present value of retirement of principal
PPS	1980$	Present value of power and supplies cost
PRD	1980$	Present value of return to debt
PRE	1980$	Present value of return to equity
PS	1980$	Regionally adjusted 1980 cost of power and supplies
PSIZE	MMtons/year	Mine size of currently least expensive coal
PSTATE	code	Current supply region code for parameters
PV	1980$/clean ton	Present value of a ton of coal
QCOAL	code	Coded sulfur category for current coal
QDEPTH	feet	Depth of current mine
QHHV	code	Higher heating value code of current coal
QOVR	percent	Overburden ratio for current coal
QPROD	MM tons	Production of current coal
QSIZE	MMtons/year	Size of current mine
QSTATE	code	Coded region for current mine
QTYPE	letter	S = surface, D = deep for current coal

Table B1-19 (contd.)

Variable	Unit	Description
RD	fraction	Rate of return on depth for mine owner
RDP	fraction	= (1+ XFLAT) (1+ RD) - 1
RE	fraction	Return to equity for mine owner
RECL	$/clean ton	Reclamation costs $/ton fixed and variable
REGION	letter	Vector of all supply region letter codes by costing regions
REP	fraction	= (1+ XFLAT) (1 + RE) - 1
RO	percent	Mine operators expected rate of return
ROY	$/clean ton	Global royalty
RP	fraction	(1 - TAX) *D* RDP + (1-D) * REP intermediate value
SDCAP	1980$	Surface deferred capital cost by mine size and overburden ratio
SEVT	$	Severance tax (fixed rate)
SICAP	1980$	Surface initial capital cost by mine size and overburden ratio
SIZE	MM tons/year	Vector of all possible mine sizes
SIZM	MM tons/year	Size of last mine read from MNCOST output
SO2LBS	lbs SO_2/MMBtu	Lbs of SO_2 per MM Btu for current coal
SPSUP	1980$	Surface power and supply by size and overburden ratio
STPMD	tons/man-day	Surface TPMD by size and overburden ratio
SUMK	1980$	SUMK(j) = sum of capital outlays from 1980 to 1980 + j
SUMKE	nominal $	SUMKE(j) = sum of nominal capital outlays from 1980 to 1980 + j
SURF		Stores all surface mine costing variables by region, mine size, and overburden ratio
SVTSR	$/clean ton	Severance tax $/clean ton

Table B1-19 (contd.)

Variable	Unit	Description
SWEL	$/clean ton	Union welfare
SWELD	$/man-day	Union welfare
TAX	percent	Corporate tax rate (typically .5)
TERM	fraction	Coefficient for deferred capital in depreciation equation
TPMD	tons/man-day	Tons per man-day for current coal
TYP	code	Type (surface/deep) of last mine read from MNCOST output
VARCLN	$/clean ton	Variable cleaning cost
XDRLAB	percent	Indirect labor (percent of direct labor)
XFLAT	percent	User-specified inflation rate
XHHV	MMBtu/ton	Higher heating value for current coal
XINSD	percent	Exposure insurance percent of direct labor cost deep
XINSS	percent	Exposure insurance percent of direct labor cost surface
XLIC	$/clean ton	License fees
YASH	percent	Ash content for currently cheapest coal
YCOST	cents/MMBtu	Cost array for currently cheapest coal
YHHV	MMBtu/ton	Higher heating value of currently cheapest coal
YIELD	fraction	= 95 percent fixed yield
YIELDD	fraction	Clean coal yield fraction - deep
YIELDS	fraction	Clean coal yield fraction - surface
YMOIST	percent	Moisture content for currently cheapest coal
YSO2LB	SO_2/MMBtu	Pounds of SO_2 per million Btu for currently cheapest coal

Table B1-20

PROGRAM RGCOST: VARIABLE INFORMATION

Variable	Type	Dimension	Unit	Storage Location	Accessed by
A	real	1	fraction		RGCOST
ABDM	real	3	$/ton/year	/PARS/	RGCOST,REDPAR(S)[a]
ACAPES	real	65	fraction	/INT/	RGCOST,INIT(S)[a]
ADDCAP	real	1	$/clean ton	/A/	RGCOST
ADDLAB	real	1	$/year		RGCOST
ADDPS	real	1	fraction	/PARS/	RGCOST,REDPAR(S)
AEL	real	65	fraction	/INT/	RGCOST,INIT(S)
AEO	real	65	fraction	/INT/	RGCOST,INIT(S)
AEPS	real	65	fraction	/INT/	RGCOST,INIT(S)
AMR	real	1	$/clean ton		RGCOST
ARO	real	30	fraction	/INT/	RGCOST,INIT(S)
ASH	real	1	percent		RGCOST
AXFLAT	real	65	fraction	/INT/	RGCOST,INIT(S)
B	real	1	fraction		RGCOST
BLACK	real	1	1980$/ton		RGCOST
BLUNG	real	3	1980$/ton	/PARS/	RGCOST,REDPAR(S)
C	real	1	fraction		RGCOST
CAPESK	real	1	percent	/A/	RGCOST,INIT
CDPR	real	1	1980$		RGCOST
CL	real	1	1980$		RGCOST
CLEAN	real	40,2	$/clean ton	/PARS/	RGCOST,REDPAR(S)
CO	real	1	1980$		RGCOST
COST	real	10	cents/MMBtu		RGCOST

Table B1-20 (contd.)

Variable	Type	Dimension	Unit	Storage Location	Accessed by
CP	real	1	1980$		RGCOST
CPS	real	1	1980$		RGCOST
CRD	real	1	1980$		RGCOST
CRE	real	1	1980$		RGCOST
D	real	1	percent		RGCOST
DCAP	real	1	1980$	/A/	RGCOST,RGCHCK(S)
DDCAP	real	6	1980$	/MAT/	RGCOST,RGCHCK(S)
DEEP	real	4	feet	/MAT/	RGCOST,RGCHCK
DEP	real	5,4,6,4			RGCHCK
DEPR	real	30	1980$		RGCOST
DEPTHM	real	1	feet		RGCHCK
DICAP	real	6,4	1980$	/MAT/	RGCOST,REGCHCK(S)
DPSUP	real	6,4	1980$	/MAT/	RGCOST,REGCHCK(S)
DPT	real	1	$/ton		RGCOST
DTPMD	real	6,4	tons/man-day	/MAT/	RGCOST,RGCHCK(S)
DWD	real	1	$/man-day	/PARS/	RGCOST,REDPAR(S)
DWEL	real	1	$/clean ton	/PARS/	RGCOST,REDPAR(S)
DWELD	real	1	$/man-day	/PARS/	RGCOST,REDPAR(S)
DWS	real	1	$/man-day	/PARS/	RGCOST,REDPAR(S)
EL	real	1	fraction	/A/	RGCOST,INIT
ELSUM	real	1	fraction	/INIT/	RGCOST,INIT(S)
EO	real	1	fraction	/A/	RGCOST,INIT
EOSUM	real	1	fraction	/INT/	RGCOST,INIT(S)
EPS	real	1	fraction	/A/	RGCOST,INIT

Table B1-20 (contd.)

Variable	Type	Dimension	Unit	Storage Location	Accessed by
EPSUM	real	1	fraction	/INIT/	RGCOST,INIT(S)
F	real	1	fraction		RGCOST
FEDD	real	1	$/ton	/PARS/	RGCOST,REDPAR(S)
FEDS	real	1	$/ton	/PARS/	RGCOST,REDPAR(S)
FEDTAX	real	1	fraction		RGCOST
FIXCLN	real	1	$/clean ton		RGCOST
GNPINF	real	1	fraction		RGCOST
IBASYR	integer	1	year		RGCOST
ICAP	real	1	1980$	/A/	RGCOST,RGCHCK
ICOAL	integer	1	code		RGCOST,REDPAR
ICODE	integer	1	code		RGCOST,REDPAR
IDATA	integer	1	flag		RGCOST,REDPAR,RGCHCK
IDEEP	integer	1	code		RGCHCK
IEND	logical	1	flag		RGCOST
IHHV	integer	1	code		RGCOST,REDPAR
IOVR	integer	1	code		RGCHCK
IPAR	integer	1	counter	argument	RGCOST,REDPAR
IREG	integer	5,14	code	code	RGCHCK
IREGN	integer	1	code	/MAT/	RGCOST,RGCHCK
ISIZE	integer	1	code		RGCHCK
ISUF	integer	1	code		RGCOST,REDPAR
ITYPE	integer	1	letter		REDPAR
IYR	integer	10	year		RGCOST
JDEEP	integer	1	index		RGCOST

Table B1-20 (contd.)

Variable	Type	Dimension	Unit	Storage Location	Accessed by
JOVR	integer	1	index		RGCOST
JSIZE	integer	1	index		RGCOST
K	real	30	1980$		RGCOST
L	integer	2	years		RGCOST,INIT
LAB	real	1	$/year		RGCOST
LCOAL	integer	1	code		RGCOST
LEVEL	real	1	fraction	/INT/	RGCOST,INIT(S)
LHHV	integer	1	code		RGCOST
LIFE	integer	2	years		RGCOST,INIT
LSTATE	integer	1	code		RGCOST
LSUF	integer	1	code		RGCOST
LTYPE	integer	1	code		RGCOST
L1	integer	1	years in future	/A/	RGCOST
L2	integer	1	years in future	/A/	RGCOST
MOIST	real	1	percent		RGCOST
NREC	integer	1	counter		REDPAR
NYR	integer	1	counter		RGCOST
ON	real	1	1980$		RGCOST
OVER	real	7	fraction	/MAT/	RGCOST,RGCHCK
OVRM	real	1	code		RGCOST,RGCHCK
PAYOVR	real	1	percent	/PARS/	RGCOST,REDPAR
PDEPTH	real	1	code		RGCOST
PDPR	real	1	1980$		RGCOST

Table B1-20 (contd.)

Variable	Type	Dimension	Unit	Storage Location	Accessed by
PL	real	1	1980$		RGCOST
PO	real	1	1980$		RGCOST
POVR	real	1	code		RGCOST
POWSUP	real	1	1980$		RGCHCK
PP	real	1	1980$		RGCOST
PPS	real	1	1980$		RGCOST
PRD	real	1	1980$		RGCOST
PRE	real	1	1980$		RGCOST
PS	real	1	1980$		RGCOST
PSIZE	real	1	MMtons/year		RGCOST
PSTATE	integer	1	code	/PARS/	RGCOST,REDPAR
PV	real	1	1980 $/clean ton		RGCOST
QCOAL	integer	1	code		RGCOST,RGCHCK
QDEPTH	real	1	feet		RGCOST
QHHV	integer	1	code		RGCOST,RGCHCK
QOVR	real	1	percent		RGCOST
QPROD	real	1	MM tons		RGCOST
QSIZE	real	1	MM tons/year		RGCOST
QSTATE	integer	1	code		RGCOST,RGCHCK
QTYPE	integer	1	letter		RGCOST
RD	real	1	fraction	/A/	RGCOST
RDP	real	1	fraction		RGCOST
RE	real	1	fraction		RGCOST
RECL	real	2,7	$/clean ton	/PARS/	RGCOST,REDPAR(S)

Table B1-20 (contd.)

Variable	Type	Dimension	Unit	Storage Location	Accessed by
REGION	integer	5,14	letter	/MAT/	RGCHCK
REP	real	1	fraction		RGCOST
RO	real	1	percent	/A/	RGCOST,INIT
ROY	real	1	\$/clean ton	/PARS/	RGCOST,REDPAR(S)
RP	real	1	fraction		RGCOST
SDCAP	real	6,7	1980\$	/MAT/	RGCOST,RGCHCK(S)
SEVT	real	1	\$	/PARS/	RGCOST,REDPAR(S)
SICAP	real	6,7	1980\$	/MAT/	RGCOST,RGCHCK(S)
SIZE	real	6	MM tons/year	/MAT/	RGCOST,RGCHCK
SIZM	real	1	MM tons/year		RGCOST,RGCHCK
SO2LBS	real	1	lbs SO_2/MMBtu		RGCOST
SPSUP	real	6,7	1980\$	/MAT/	RGCOST,RGCHCK(S)
STPMD	real	6,7	tons/man-day	/MAT/	RGCOST,RGCHCK(S)
SUMK	real	30	1980\$		RGCOST
SUMKE	real	30	nominal \$		RGCOST
SURF	real	5,4,6,7			RGCHCK
SVTSR	real	1	\$/clean ton	/PARS/	RGCOST,REDPAR(S)
SWEL	real	1	\$/clean ton	/PARS/	RGCOST,REDPAR(S)
SWELD	real	1	\$/man-day	/PARS/	RGCOST,REDPAR(S)
TAX	real	1	percent	/A/	RGCOST
TERM	real	30	fraction	/INT/	RGCOST,INIT(S)
TPMD	real	1	tons/man-day		RGCOST,RGCHCK
TYP	integer	1	code		RGCHCK

Table B1-20 (contd.)

Variable	Type	Dimension	Unit	Storage Location	Accessed by
VARCLN	real	1	$/clean ton		RGCOST
XDRLAB	real	1	percent	/PARS/	RGCOST,REDPAR(S)
XFLAT	real	1	percent	/A/	RGCOST,INIT
XHHV	real	1	BTU/lb		RGCOST
XINSD	real	1	percent	/PARS/	RGCOST,REDPAR(S)
XINSS	real	1	percent	/PARS/	RGCOST,REDPAR(S)
XLIC	real	1	$/clean-ton	/PARS/	RGCOST,REDPAR(S)
YASH	real	1	percent		RGCOST
YCOST	real	10	cents/MMBtu		RGCOST
YHHV	real	1	MMBtu/clean ton		RGCOST
YIELD	real	1	fraction		RGCOST
YIELDD	real	40	fraction	/PARS/	RGCOST,REDPAR(S)
YIELDS	real	40	fraction	/PARS/	RGCOST,REDPAR(S)
YMOIST	real	1	percent		RGCOST
YSO2LB	real	1	lbs SO_2/MM Btu		RGCOST
YY	real	1	fraction		RGCOST

[a] (S) means the variable is initialized in this subroutine.

PP = present value of retirement of principal (1980\$)

PRD = present value of debt cost (1980\$)

PL = present value of labor-related cost (1980\$)

PPS = present value of power and supplies cost (1980\$)

PO = present value of other nonescalating costs (1980\$)

$PDPR$ = present value of depreciation of capital (1980\$)

$YIELD$ = cleaning yield (data)

$SIZE$ = mine size (tons/yr) (hard wired)

$LIFE$ = mine lifetime (yr) (hard wired)

$SEVT$ = severance tax (fixed rate) (data)

$FEDTAX$ = federal royalty (data)

and the coefficients A, B, and C are functions of the depletion allowance and corporate tax rate.

The following sections show how PRE, PP, PRD, PL, PPS, PO, PDPR, A, B, and C are determined.

1.4.1.1 **PRE, PP, and PRD.** The present values of the return to equity (PRE), interest (PRD), and principal (PP) are relatively straightforward to compute. These three terms are related to the stream of capital investments K.

$$PRE = (1\text{-}D)REP \sum_{i=1}^{LIFE} \frac{\sum_{n=1}^{i} K(n)\,(1+XFLAT)^n}{((1+RO)(1+XFLAT))^i} \qquad \text{[Eq 24]}$$

$$PRD = D * RDP \sum_{i=1}^{LIFE} \frac{\sum_{n=1}^{i} K(n)(1+XFLAT)^{n}}{((1+RO)(1+XFLAT))^{i}} \qquad \text{[Eq 25]}$$

$$PP = \frac{\sum_{i=1}^{LIFE} K(i)}{(1+RO)^{Life}} \qquad \text{[Eq 26]}$$

where D = debt ratio (data)

REP = (1 + XFLAT)(1 + RE) - 1

RDP = (1 + XFLAT)(1 + RD) - 1

$XFLAT$ = inflation rate (data)

RE = real pretax rate of return on equity (data)

RD = real pretax cost of debt (data)

$K(i)$ = stream of capital investment (see below)

RO = the real discount rate:

$$\frac{1 + (1 - TAX)D * RDP + (1 - D)REP}{1 + XFLAT} - 1$$

TAX = corporate tax rate (data).

To find K(j) we follow the EIA methodology of spreading the deferred capital over the lifetime of the mine. We evenly distribute 10 percent of deferred capital over the first and last quarters of the mine life and 90 percent over the second and third quarters, and escalate each outlay to the year in which it is made:

$$K(1) = (ICAP + DCAP * \frac{.05}{L1})(1+ CAPESK), \qquad \text{[Eq 27]}$$

$$K(j) = (DCAP * \frac{.05}{L1} * (1+ CAPESK)^j \quad (where\ j=2,L1), \qquad \text{[Eq 28]}$$

$$K(j) = (DCAP * \frac{.9}{L2-L1+1} * (1+ CAPESK)^j \quad (where\ j=L1+1,L2-1), \qquad \text{[Eq 29]}$$

$$K(j) = (DCAP * \frac{.05}{L1} * (1+ CAPESK)^j \quad (where\ j=L2,L-1), \text{ and} \qquad \text{[Eq 30]}$$

$$K(LIFE) = 0 \qquad \text{[Eq 31]}$$

where $K(j)$ = stream of capital investments (1980$)

$ICAP$ = initial capital investment (1980$; data from MNCOST)

$DCAP$= aggregated deferred capital investment over the life of the mine (1980$; data from MNCOST)

$L1$ = nearest integer to .25 * LIFE

$L2$ = nearest integer to .75 * LIFE

$LIFE$ = mine life

$CAPESK$= real escalation rate of capital costs (data)

1.4.1.2 **PL, PPS, and PO**. The calculations for PL (the present value of labor-related costs), PPS (the present value of power and supplies cost), and PO (the present value of other nonescalating costs) are as follows:

$$PL = \sum_{i=1}^{LIFE} \frac{LAB * (1+ EL)^i}{(1+ RO)^i} \qquad \text{[Eq 32]}$$

$$PPS = \sum_{i=1}^{LIFE} \frac{PS * (1+ EPS)^i}{(1+ RO)^i} \qquad \text{[Eq 33]}$$

$$PO = \sum_{i=1}^{LIFE} \frac{ON * (1+EO)^i}{(1+RO)^i} \qquad [Eq\ 34]$$

where LAB = regionally adjusted 1980 labor cost

PS = regionally adjusted 1980 cost of power and supplies (data from MNCOST)

ON = other 1980 regional costs.

Table B1-18 lists the components of LAB and ON. LAB consists of the wage rate, the costs that are a percentage of the wage rate, and other costs. The wage rate and other costs are obtained from the EIA input tape in 1975 dollars and are escalated to 1980 dollars by multiplying by GNPINF (GNP inflator). The equations used to calculate LAB are of the following form (those in this example are for surface mines):

$$LAB = \frac{DWS * SIZE}{TPMD} \qquad [Eq\ 35]$$

$$ADDLAB = (PAYOVR + XDRLAB + \frac{XINSS}{100})\ LAB \qquad [Eq\ 36]$$

$$+ (VARCLN + RECL(2,JOVR) + SWEL)\ YIELD * SIZE + \frac{SWELD}{TPMD} * QSIZE$$

$$LAB = (LAB + ADDLAB)\ GNPINF \qquad [Eq\ 37]$$

Variable descriptions may be found in Table B1-19. ON includes the other costs that vary by region and type of mine. These costs are assumed to be obtained in 1980 dollars. The following equation shows how ON is calculated for surface mines:

$$ON = (ROY + AMR + BLACK + SVTSR + FIXCLN) * YIELD * SIZE + ADDCAP \qquad [Eq\ 38]$$

where ADDCAP, additional capital expenditures, is calculated as follows:

$$ADDCAP = (RECL(1,JOVR) + XLIC) * GNPINF * YIELD * SIZE \qquad [Eq\ 39]$$

The cleaning costs for AUSM coal categories are set to zero because cleaning is handled in the washing program. EIA coals are not washed within the washing program so the costs are not necessarily zero.

The fixed and variable cleaning costs for coal types ZA, ZB, ZC, ZD, and ZE are set in the program RGCOST to the following values: VARCLN = .56, FIXCLN = 1.4, respectively. The EIA model included higher cleaning costs (and lower yields) applied to metallurgical use of these coals. When purchased by utilities, such extraordinary levels are not used [5].

1.4.1.3 **PDPR**. PDPR, the present value of depreciation deductions, depends on the levelized value of the depreciated capital (DEPR). The levelized value of the depreciated capital is calculated slightly differently from the way it is calculated by the EIA-RAMC mine costing routine. We follow EIA's breakdown of deferred capital but assume that initial capital is divided into components that are depreciated either over the lifetime of the mine or for 5 or 10 years inferred from the stream of deferred capital expenditures. The equations for determining DEPR are outlined in Table B1-21.

The present value of depreciation on deferred capital investments is then calculated:

$$PDPR = \sum_{j=1}^{LIFE} \frac{DEPR(j)}{(1+RO)^j \, (1+XFLAT)^j} \qquad \text{[Eq 40]}$$

where *DEPR* is as outlined in Table B1-21 and RO is the real discount rate.

1.4.1.4 **A, B, and C**. The coefficients A, B, and C depend on the depletion allowance, the corporate tax rate, severance taxes, and federal royalty taxes. The calculation of after-tax costs is complicated by the existence of two possible formulas for calculating the depletion allowance. The depletion allowance is equal to 10 percent of the selling price or 50 percent of gross profit, whichever is less. A test is performed to determine which formula should be used for computing the tax:

Case 1: depletion allowance is 10 percent of sales if

$$PRE + PP \geq \frac{1 - .5\ TAX}{4(1-TAX)} (PL + PPS + PO + PRD) + \frac{5 - .5\ TAX}{4(1-TAX)} * PDPR. \qquad \text{[Eq 41]}$$

Table B1-21
EQUATION FOR CAPITAL STREAM USED TO DETERMINE CAPITAL DEPRECIATION

$$\mathrm{DEPR(j)} = \frac{ICAP}{LIFE} + \mathrm{DCAP} * \mathrm{TERM(j)}.$$

j	Term (i) Costs incurred every 5 years	Costs incurred every 10 years
1-5	$\frac{.1}{30}$	
6-10	$\frac{.1}{30} * (Z)^{5}$	
11-15	$\frac{.1}{30} * (Z)^{10}$	$\frac{.9/2}{10} * (Z)^{10}$
16-20	$\frac{.1}{30} * (Z)^{15}$	$\frac{.9/2}{10} * (Z)^{10}$
21-25	$\frac{.1}{30} * (Z)^{20}$	$\frac{.9/2}{10} * (Z)^{20}$
26-30	$\frac{.1}{30} * (Z)^{25}$	$\frac{.9/2}{10} * (Z)^{20}$

Note: Z = (1+ XFLAT)(1+ CAPESK)

In this case,

$$A = \frac{1}{(1 - .9 * TAX) * F} \qquad \text{[Eq 42]}$$

$$B = \frac{1 - TAX}{(1 - .9 * TAX) * F} \qquad \text{[Eq 43]}$$

$$C = \frac{-TAX}{(1 - .9 * TAX) * F} \qquad \text{[Eq 44]}$$

Case 2: Depletion allowance is 50 percent of gross profit if

$$PRE + PP < \frac{1 - .5\ TAX}{4(1-TAX)}(PL + PPS + PO + PRD) + \frac{5 - .5\ TAX}{4(1-TAX)} * PDPR. \qquad \text{[Eq 45]}$$

In this case,

$$A = \frac{1}{(1 - .5\ TAX) * F} \qquad \text{[Eq 46]}$$

$$B = \frac{1}{F} \qquad \text{[Eq 47]}$$

$$C = \frac{-.5\ TAX}{(1 - .5\ TAX) * F} \qquad \text{[Eq 48]}$$

where F is one minus the sum of the severance tax (SEVT) and the federal royalty tax (FEDTAX).

RGCOST reports the minimum cost mine for each region and coal type. The present value costs of the mines are used to select the mine to be reported. The cost reported is not the present value, but rather the real levelized cost of a ton of coal produced by a mine opened in each time period. The cost of coal in a time period is calculated as follows:

$$\begin{aligned} COST(t) = \{((A * CRE + CP) + B * CRD + C * CDPR)(1 + CAPESK)^t + CL * \qquad \text{[Eq 49]} \\ (1 + EL)^t + CPS * (1 + EPS)^t + CO * (1 + EO)^t)\} * 100/(YIELD * SIZE * XHHV) \end{aligned}$$

where $CRE =$ levelized return on equity (1980$)

$CP =$ levelized retirement of principal (1980$)

$CRD =$ levelized debt cost (1980$)

$CDPR =$ levelized depreciation allowance (1980$)

$CL =$ levelized labor-related costs in 1980 (discussed above)

$CPS =$ levelized cost of power and supplies (discussed above)

$CO =$ levelized cost of other costs in 1980 (discussed above)

$XHHV =$ higher heating value of coal

and A, B, and C depend on the tax case (defined above); and CAPESK, EL, and EPS are the real escalation of capital, labor, and power and supplies, respectively, which are inputs to the model.

CRE, CP, CRD, CDPR, CL, CPS, and CO are the levelized values of the corresponding present value terms. The following equation shows how the levelized cost is calculated from the present value cost:

$$CXXX = PXXX * \frac{(1-RO)^L * RO}{(1+RO)^L - 1}. \qquad \text{[Eq 50]}$$

The levelized cost is reported for the years requested. Up to 10 years can be reported; the latest possible year is 2044 because the escalator arrays are dimensioned 65.

1.4.2 Data Handling

RGCOST has four input files and one output file. Table B1-22 identifies the input files to the program, and Tables B1-19 and B1-20 provide descriptions of the variables used in RGCOST. The output file MINCOS is documented in Table B1-23.

1.4.3 Subroutine Descriptions

RGCOST has six subroutines: DETHHV, SUFCON, INIT, REDPAR, RGCHCK, and SUFCAT. Figure B1-4 shows where these routines are called and which general tasks they perform.

Table B1-22

PROGRAM RGCOST: INPUT FILES

RGCOST has four input files: MINES, PARMS, MMAT, and USERRG. Files MINES and PARMS are documented in Table B1-10 as output and input files, respectively, to QUANT. File MMAT is the output file of MNCOST and is documented in Table B1-16. File USERRG is documented below.

Input File USERRG

Card	Column	Format	Contents	Variable Name	Current Values
1	1-2	I2	number of years	NYR	7
2	1-50	10(I4,1X)	years	IYR	1980,1985,1990, 2000,2010,2020 2040
3	1-10	F10.4	inflation rate	XFLAT	.06
4	1-10	F10.4	real after-tax rate of return on equity	RE	.061
5	1-10	F10.4	real rate of cost of debt	RD	.015
6	1-10	F10.4	real escalation of capital	CAPESK	0.0
7	1-10	F10.4	debt ratio	D	.3
8	1-10	F10.4	real escalation of power and supplies	EPS	0.0
9	1-10	F10.4	real escalation of labor	EL	.01
10	1-10	F10.4	corporate tax rate	TAX	.5
11	1-10	F10.4	real escalation of other costs	EO	0.0

Table B1-23
PROGRAM RGCOST: OUTPUT FILE (MINCOS)

Card	Column	Format	Contents	Variable Name
1	1	I1	Coal source flag	IFLAG
2	1-2	I2	Number of years included	NYR
3	1-50	10(I4,1X)	Years	IYR(10)
4	1-10	F10.3	Inflation rate	XFLAT
5	1-10	F10.3	Real after-tax rate of return on equity	RE
6	1-10	F10.3	Real rate of cost of debt	RD
7	1-10	F10.3	Real escalation of capital	CAPESK
8	1-10	F10.3	Debt ratio	D
9	1-10	F10.3	Real escalation of power and supplies	EPS
10	1-10	F10.3	Real escalation of labor	EL
11	1-10	F10.3	Corporate tax rate	TAX
12	1-10	F10.3	1975$ to 1980$ inflator	GNPINF
Card 13 to end of file				
	1-2	I2	Supply region code	LSTATE
	3-4	I2	Sulfur code*	LCOAL
	5	I1	HHV code	LHHV
	6-85	10(F8.3)	Cost of coal in up to 10 years defined above in IYR	COST(10)
	86-91	F6.2	HHV	YHHV
	92-97	F6.1	Sulfur content	YSO2LBS
	98-103	F6.1	Moisture content	YMOIST
	104-109	F6.1	Ash content	YASH

Note: This file contains the user parameters used to calculate minemouth costs, along with the minemouth cost of coal from the least expensive mine by region, coal type, and time period.

*AUSM sulfur codes are 12 minus the codes listed in codelist K.

1.4.3.1 Subroutine DETHHV

Arguments: LHHV, YHHV, MODE.

Called by: RGCOST.

Calls: None.

Task: Converts EIA higher heating values into number codes and assigns an actual higher heating value to be used. Called only when EIA-RAMC reserves data are being used.

Method: The following table shows the relationship used between EIA codes, number codes, and the higher heating values that are assigned.

EIA Code	*Number Code*	*HHV*
Z	1	27
H	2	24.5
M	3	21.5
S	4	17.5
L	5	14

DETHHV is called with the character code LHHV and returns to the integer code MODE and the higher heating value YHHV.

1.4.3.2 Subroutine SUFCON

Arguments: ISULF, IHHV, INDEX.

Called by: RGCOST, REDPAR.

Calls: None.

Task: Converts EIA sulfur and higher heating value codes into an index ranging from 1 to 40 (= 5 * 8). This code is used in arrays which are coal type specific.

Method: The sulfur category letters are converted to numbers from 0 to 4. An index is set equal to eight times the higher heating value plus the sulfur number. This yields a number from 1 to 40 for use as an index into coal-specific arrays.

1.4.3.3 **Subroutine INIT**

Arguments: None.

Called by: RGCOST.

Calls: None.

Task: Calculates escalators and other terms that do not change and that are used throughout the main routine.

Method: Initializes the following escalators: AXFLAT, ARO, ACAPES, AEL, ELSUM, EPSUM, AEO, AEPS, and EOSUM. Also initializes TERM and LEVEL. TERM is used in calculating DEPR; LEVEL is the levelizing factor.

1.4.3.4 **Subroutine REDPAR**

Arguments: IDATA, IPAR.

Called by: RGCOST.

Calls: SUFCON.

Task: Reads the parameter file.

Method: Reads one region's regional and coal-specific parameters. The first time REDPAR is called (as indicated by flag IPAR), it reads the global parameters. Argument IDATA indicates whether EIA or AUSM parameters are required. The file PARMS contains both sets of parameters. If AUSM parameters are required, the EIA parameters must first be skipped.

1.4.3.5 Subroutine RGCHCK

Arguments: IDATA, OSTATE, IREGN.

Called by: RGCOST.

Calls: None.

Task: Determines if the current mine is in the costing region that is in storage. If not, the current costing region's values are placed in local storage.

Method: On the first call to RGCHCK (IREGN = 0), the entire file MMAT is read into storage. RGCHCK is also initialized to 1. On the first call and all subsequent calls, the appropriate costing region is then determined. A check is made to determine whether the current mine costing region is suitable for this region. If so, the routine returns; otherwise, the appropriate values (for cost components relating to surface and deep mines) are put into the arrays SICAP, DICAP, SDCAP, DDCAD, STPMD, DTPMD, SPSUM, and DPSUP.

Table B1-24 lists the correspondence between the model mine costing regions and the EIA and AUSM supply regions. There is a direct mapping between the supply regions and costing regions 1 through 4. The fifth region is coal type specific. Only certain coals in Wyoming are in the fifth costing region. The RAMC input file flagged supply regions which belonged in costing region 5. This information was used to determine which AUSM coals belonged in that region.

1.4.3.6 Subroutine SUFCAT

Arguments: CCOAL, ICOAL.

Called by: RGCOST.

Calls: None.

Task: Converts EIA letter sulfur categories to integer codes.

Method: The conversion is as follows:

EIA Code	*Integer Code*
A	8
B	7
C	6
D	5
E	4
F	3
G	2
H	1

A default value of 9 is returned if no match is found. CCOAL is the EIA code and ICOAL is the integer code returned.

1.4.4 Flowchart of RGCOST

Figure B1-4 gives the flowchart of RGCOST.

1.4.5 Variable Definitions

Tables B1-19 and B1-20 summarize the variables used in RGCOST.

Table B1-24

MODEL MINE, EIA, AND AUSM SUPPLY REGIONS

Model Mine Region	EIA Region	AUSM Region
1	West Virginia, South; Virginia; Kentucky, East; Tennessee; Alabama	7, 8, 10, 11, 12, 14, 15, 19
2	Pennsylvania; Ohio; Maryland; West Virginia, North	1, 2, 3, 4, 5, 6, 9
3	Kentucky, West; Illinois; Indiana; Iowa; Missouri; Kansas; Arkansas; Oklahoma	13, 16, 17, 18, 20, 21, 22, 23, 24
4	Texas; North Dakota; South Dakota; Montana, East; Montana, West; Wyoming, South; Utah; Colorado, North; Colorado, South; Arizona; New Mexico; Alaska; Washington; Wyoming	25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35
5	Wyoming, North; and coal types SA, SD, and SF in Wyoming	Coal types (2,2), (3,2), (4,2), and (5,2) in supply region 31

1.5 Delivered Prices (Program LEASTC)

Program LEASTC generates coal cost data, which are transmitted to AUSM via file E6. The file COST, which is created by LEASTC, is reformatted by the intermediate program MAKE6 to obtain E6. MAKE6 also overwrites the period 1 delivered cost with the actual price paid and interpolates a cost for period 2 based on the actual period 1 cost and the cost in period 3.

A central task of LEASTC is determination of the least delivered costs at which each demand region may obtain each coal type. Coal types are distinguished by m,h indices that represent sulfur content and higher heating value (HHV) categories of processed coals.[2] The least cost of a coal type delivered to a demand region is chosen from all supply regions that produce that coal type.

---

[2] The sulfur category of an unprocessed ("raw") coal is designated by the index k. Except for this designation, k is identical in meaning to m.

A single raw coal type (kh) may be washed to several lower sulfur coal types. Conversely, a single processed coal type may be produced from several raw coal types in a single coal supply region. It is assumed, however, that no coal changes its HHV category as a result of processing. Both the preshipment cost and the higher heating value of processed coals falling within an mh coal type may vary depending on the kh type of the raw coal and on the technology used for washing. Supplier i may thus be able to offer for sale, within a single mh coal type, both cheaper, heavier coals and more expensive, lighter coals. From these alternatives, the preprocessor selects the coal produced by i that presents the least costly alternative for individual demand regions. A formal description of this "unconstrained" coal washing/transportation algorithm appears in Reference 2, and the implementation of the algorithm is described below.[3]

Least-cost coals are calculated for a maximum of ten user-specified years, for example: 1980, 1985, 1990, 2000, 2010, 2020, and 2040. The "best offer" of each coal type made to each demander from among all suppliers is printed for each of these years. In addition, the best offers of locally mined coals are also printed.

Figure B1-5 depicts the logical flow of the coal preprocessor. In LEASTC, the ordering of the sulfur categories is reversed from the ordering in the AUSM, with high numbers corresponding to low-sulfur coals and low numbers corresponding to dirtier, high-sulfur coals. This ordering is again reversed when the cost output file is processed by MAKE6.

1.5.1 Central Algorithms and Basic Assumptions

The primary iterative by which least-delivered coal prices are generated is the processed coal type (m). Within this structure, HHV categories (h) are processed at a primary level, supply regions (i) are processed at a secondary level, and years (y) are spanned last. For each m,h,i,y combination the least cost of coal delivered to each demand region (j) is determined. An [i,j] matrix (CHEAPO) is filled that contains

---

[3] AUSM sulfur categories, HHV categories, supply regions, demand regions, and processing technologies are described in the AUSM system design document [7].

Figure B1–5
LOGICAL FLOW OF LEASTC

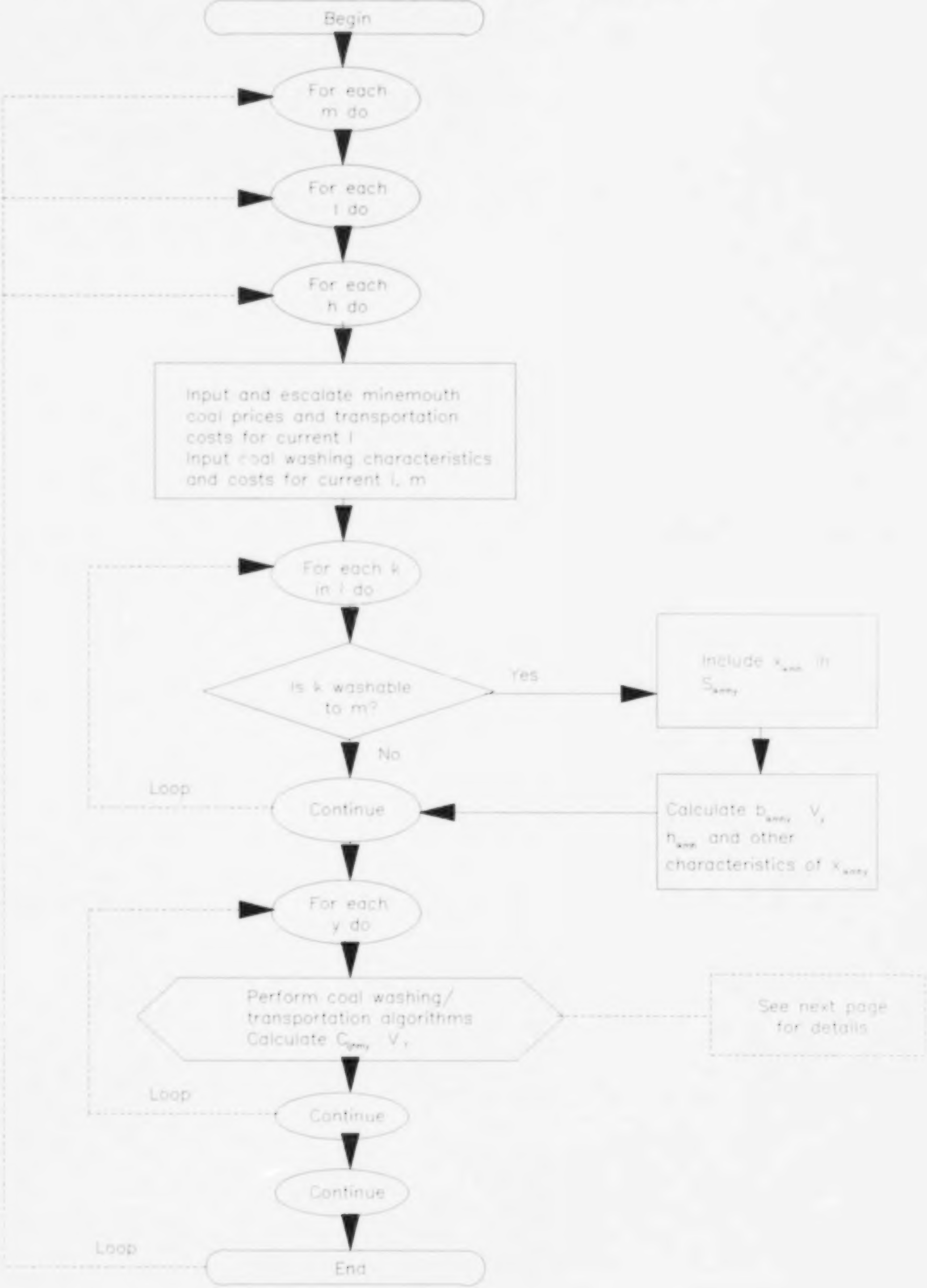
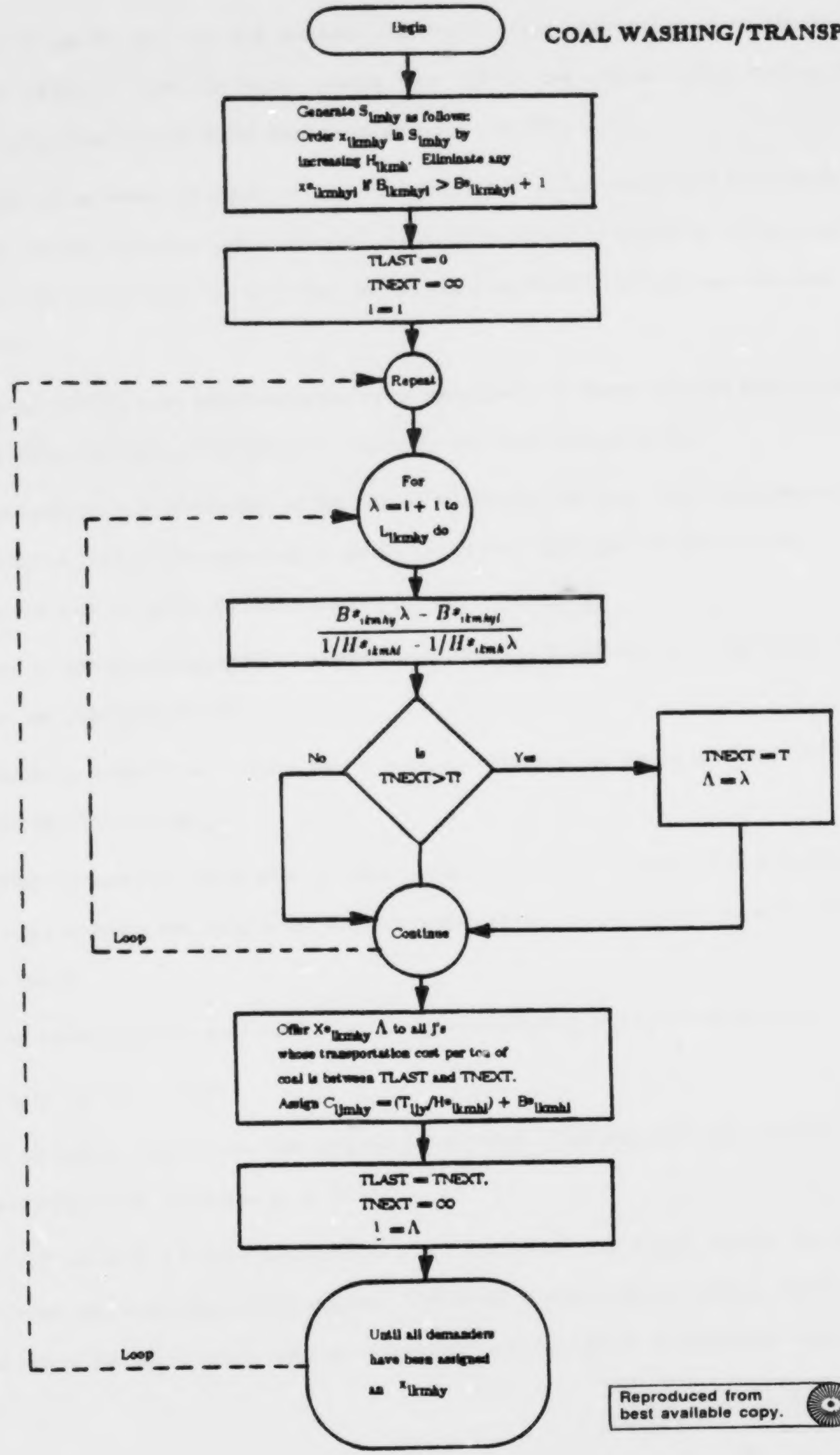

Begin
For each m do
For each l do
For each h do
Input and escalate minemouth coal prices and transportation costs for current l
Input coal washing characteristics and costs for current l, m
For each k in l do
Is k washable to m?
Yes
No
Include x_{kmh} in S_{kmhy}
Calculate b_{kmhy}, V_y
h_{kmh} and other characteristics of x_{kmhy}
Loop
Continue
For each y do
Perform coal washing/ transportation algorithms
Calculate C_{jkmhy}, V_y
See next page for details
Loop
Continue
Continue
Loop
End

Figure B1-5 (contd.)

COAL WASHING/TRANSPORTATION


Begin
Generate S_{lmhy} as follows:
Order x_{lkmhy} in S_{lmhy} by
increasing H_{lkmh}. Eliminate any
x^{e}_{lkmhyl} if $B_{lkmhyl} > B^{e}_{lkmhyl} + 1$
TLAST = 0
TNEXT = ∞
l = 1
Repeat
For
$\lambda = l + 1$ to
L_{lkmhy} do
$\frac{B^{e}_{lkmhy}\lambda - B^{e}_{lkmhyl}}{1/H^{e}_{lkmhl} - 1/H^{e}_{lkmh}\lambda}$
Is
TNEXT>T?
No
Yes
TNEXT = T
$\Lambda = \lambda$
Continue
Loop
Offer $X^{e}_{lkmhy}\Lambda$ to all j's
whose transportation cost per ton of
coal is between TLAST and TNEXT.
Assign $C_{ljmhy} = (T_{ljy}/H^{e}_{lkmhl}) + B^{e}_{lkmhl}$
TLAST = TNEXT,
TNEXT = ∞
l = Λ
Until all demanders
have been assigned
an x_{lkmhy}
Loop

Reproduced from
best available copy.

the best offers of mh by each i to each demander j in year y. Four additional matrices, dimensioned identically to CHEAPO, store the higher heating value (HHV), ash content (ASH), washing level (KWASH), and raw coal type (KORIG) that correspond to the best offers of mh.

The least cost at which *any* supply region i can deliver mh to each demand region j in a given year y is found by keeping i constant and scanning the remaining dimension in CHEAPO. (This is done by function SELLOC to find least-cost local coals and by function SELECT to find least-cost coals on a national level.)

Subroutine OFFER is the coordinating routine for determining the lowest delivered price at which a supplier can sell an mhi coal to each demander. There are four steps in this procedure:

1. Determine all ways of obtaining an mh coal in i by washing raw coals. Khi is washable to mhi if (1) km is mined in i and (2) the technology is present in i to wash kh to mh. (Feasible washing methods and existing raw coals are accessed in subroutine UPCHAR.)

2. Sort all mhi by increasing HHV. Eliminate any mhi if it is preceded by a coal having a lower preshipment cost (subroutine ELIM).

3a. Assign an initial lower bounding cost, $r_0 \leftarrow \$0/\text{ton}$. Flag the mhi having the lowest HHV as the currently offered coal, $C \leftarrow (\text{mhi})_0$.

3b. Find the next mhi ranked after C, which is a cheapest source of coal for some demand regions. Assign an upper bounding cost equal to the minimum transportation cost at which it becomes a less costly coal source than C.

3c. All demand regions whose transportation costs are between t_0 and t_1 are offered coal C.

3d. $r_0 \leftarrow r_1$ and $C \leftarrow \text{mhi}$.

4. If all demand regions have been assigned an mhi, stop. If all mhi have been scanned, then (1) $r_1 \leftarrow \infty$ and (2) go to 3c. Otherwise, go to 3b.

LEASTC serves as a scoping mechanism for the national-level coal supply module. As such, coal assignments are made assuming infinite supplies. This factor is relaxed in the national version through the use of annual demand estimates, tracking of depletion, and optimization of assignments through linear programming techniques. LEASTC has been used for determining price-setting coals.

1.5.1.1 **Forced Washing Scenarios.** Subroutine FWASH allows the user to specify special forced washing scenarios. FWASH implements an algorithm as developed by James F. Skea [9]. This algorithm is described in greater detail in Figure B1-6. Figure B1-6 also serves as a flowchart for subroutine FWASH.

1.5.2 Data Handling

LEASTC reads data from three files and reads scenario parameters from a fourth file. There are four output files besides standard output, which is reserved for error messages. File I/O is depicted in Figure B1-7. The eight other types of files are discussed below.

1.5.2.1 **Minemouth Coal Prices.** This input file is assigned unit 21. The information is contained in file CPRICE. This file is read in its entirety during the first call to subroutine UPCHAR and the data are stored in the array PRICMM. The format of file CPRICE is shown in Table B1-25.

The minemouth coal price file was created as follows. Michelson and Green's minemouth costs [8] were merged with results obtained from the model mines program. The former were available only for coals actually produced in the 1975-80 period, the latter only for coals included in the DOE/EIA demonstrated reserves base. There were some discrepancies between the two data sets. Minemouth projections for 1980 and model mine estimates for 1990 were used subject to the following restrictions:

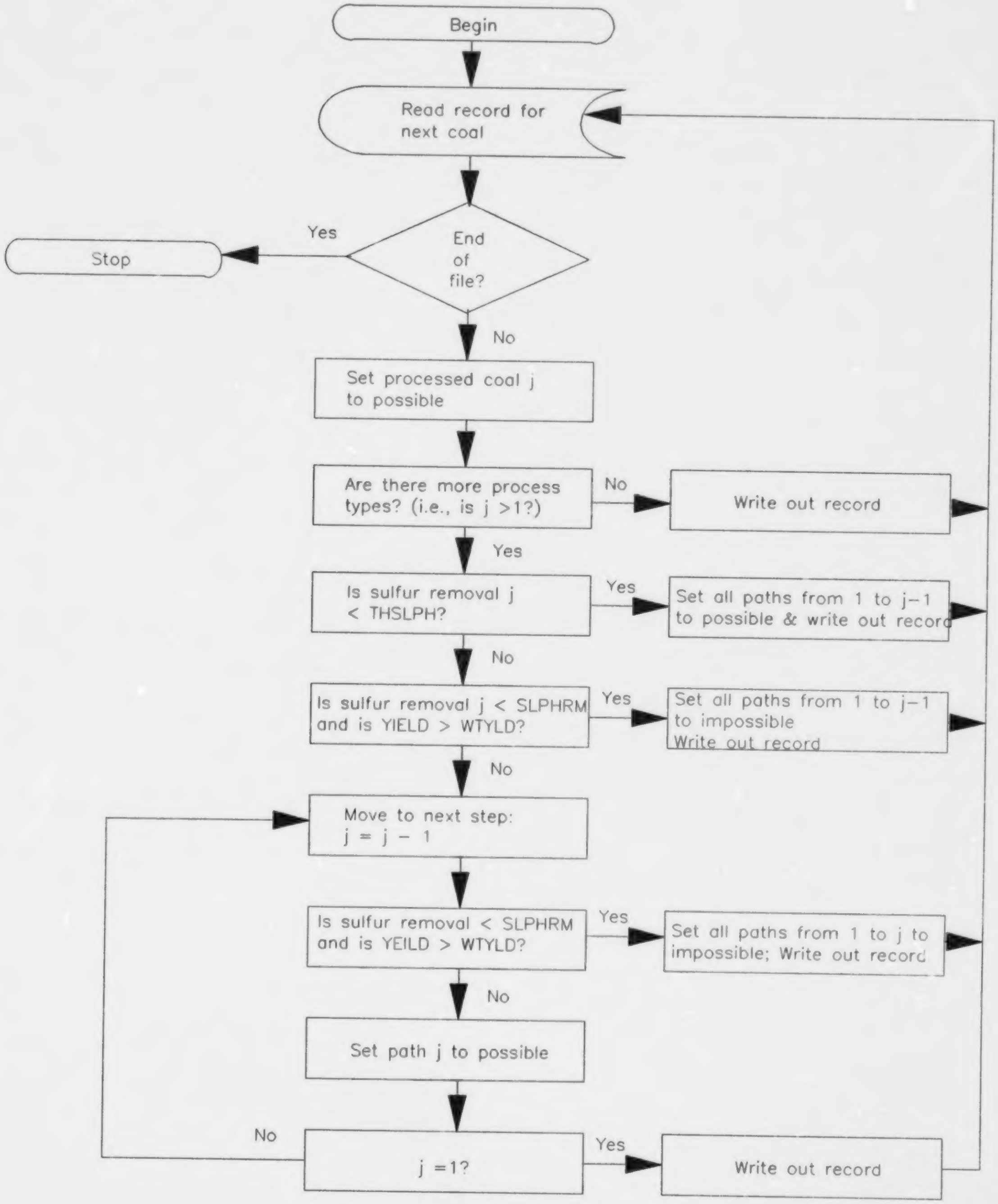
1. When both types of data were present, a 1985 minemouth cost was calculated as an average of the 1980 and 1990 costs.

2. When a model mine cost was absent, indicating a lack of significant reserves, the 1980 Michelson and Green estimate was not used. Instead, the cost was set to zero for all years, causing LEASTC to ignore that coal type in that region.

3. When the Michelson and Green cost was absent, the cost was set to zero for 1980 and 1985, and the model mine cost was used for 1990. This causes LEASTC to ignore the coals in the first few years, but allows new mines to be opened by 1990. This completes preparation of the minemouth cost data file used with the model mine cost equations.

Figure B1-6

HEURISTIC FOR DETERMINING PERMISSIBLE PREPARATION PATHS UNDER MANDATORY WASHING SCENARIO



Begin
Read record for next coal
Yes
End of file?
Stop
No
Set processed coal j to possible
Are there more process types? (i.e., is j >1?)
No
Write out record
Yes
Is sulfur removal j < THSLPH?
Yes
Set all paths from 1 to j-1 to possible & write out recorc
No
Is sulfur removal j < SLPHRM and is YIELD > WTYLD?
Yes
Set all paths from 1 to j-1 to impossible Write out record
No
Move to next step: j = j - 1
Is sulfur removal < SLPHRM and is YEILD > WTYLD?
Yes
Set all paths from 1 to j to impossible; Write out recorc
No
Set path j to possible
No
j =1?
Yes
Write out record

Figure B1-7
LEASTC FILE I/O

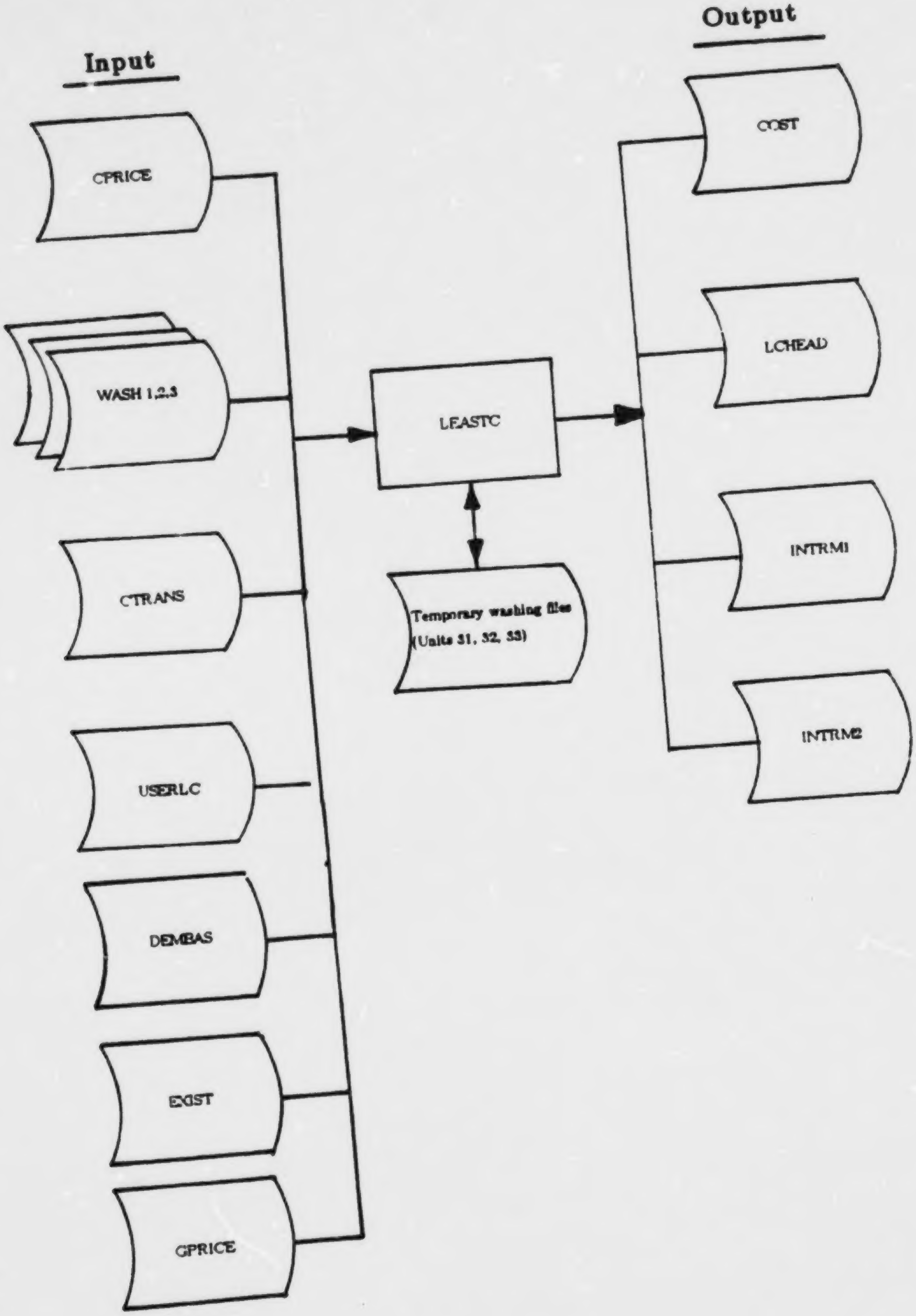


Table B1-25
FILE CPRICE FORMAT

This file consists of 12 header records followed by one section for each of 385 distinct supply region-sulfur category combinations. Data within each section are organized as follows:

Card	Column	Format	Contents	Unit/Codelist
1	1	I1	Coal source flag	1=AUSM 2=EIA
2	1-2	I2	Number of years included	Integer
3	1-50	10(I4,1X)	Years	Dates
4	1-10	F10.3	Inflation rate	fraction
5	1-10	F10.3	Real after-tax of return on equity	fraction
6	1-10	F10.3	Real rate of cost of debt	fraction
7	1-10	F10.3	Real escalation of capital	fraction
8	1-10	F10.3	Debt ratio	fraction
9	1-10	F10.3	Real escalation of power and supplies	fraction
10	1-10	F10.3	Real escalation of labor	fraction
11	1-10	F10.3	Corporate tax rate	fraction
12	1-10	F10.3	1975$ to 1980$ inflator	fraction
Card 13 to end of file				
	1-2	I2	Supply region code	Codelist J
	3-4	I2	Sulfur code	Codelist K
	5	I1	HHV code	Codelist N
	6-85	10(F8.3)	Cost of coal in up to 10 years defined above	cents/MMBtu
	86-91	F6.2	HHV	MMBtu/ton
	92-97	F6.1	Sulfur content	lbs/MMBtu
	98-103	F6.1	Moisture content	lbs/MMBtu
	104-109	F6.1	Ash content	fraction

When the user specifies escalation rates for minemouth costs, a few additional modifications to the file are made on the basis of production and demonstrated reserves. This is done in order to eliminate coals having limited reserves and coals for which good 1980 cost estimates could not be obtained. If the coal has annual production of less than 0.2 million tons, or reserves of less than 150 million tons, its cost is set to zero in order to prevent LEASTC from allocating large quantities of it to demand regions in 1980 and 1985. Costs for 1985 and 1990 are unchanged because they are overwritten later by the user-specified escalated values.

These functions are handled by subroutine COSTRD. This subroutine takes data from three files: GPRICE (unit 22)—contains actual period 1 minemouth costs and is described in Table B1-26; EXIST (unit 23)—contains data on period 1 production and is described in Table B1-27; DEMBAS (unit 24)—contains demonstrated reserve tonnage and was described in a previous section.

In all cases after the LEASTC run, the COST output file is modified by MAKE6 by substituting actual prices paid (where these prices existed) for the estimated least delivered cost for 1980. Costs in 1985 are then calculated by averaging 1990 and new 1980 costs.

1.5.2.2 **Coal Washing Characteristics.** This information is represented by input files WASH1, WASH2, and WASH3, respectively, for bituminous, sub-bituminous, and lignite coals (units 11, 12, and 13). Before results are computed for a new processed coal type (sulfur-HHV category combination), washed coal characteristics for the designated sulfur category are read from the washing characteristics file pertaining to the designated HHV category. WASH1, WASH2, and WASH3 are read one complete time, under execution-time formats, for each processed sulfur category.

Four kinds of information, all of which pertain to supplies of the current processed coal type, are read from the coal washing characteristics files. (Storage variables are in parentheses.) This information is (1) the cost of processing one ton of raw coal (COST), (2) the weight yield (SHRINK), (3) the ash content (ASHW), and (4) the technical level of preparation (KWASHW).

The formats of WASH1, WASH2, and WASH3 can be found in Table B1-28. It should be noted that these files are not needed when EIA coal data are processed. In that case, washing files are created by subroutine WASHER.

Table B1-26
FILE GPRICE FORMAT

This file contains one record for every possible region/coal-type combination. Coals that do not exist in period 1 have costs set equal to zero.

Column	Format	Contents	Unit/ Codelist
1-2	I2	Supply region	Codelist J
3-4	I2	Sulfur category[a]	Codelist K
5-6	I2	HHV category	Codelist N
7-17	F11.3	Actual minemouth cost, period 1	cents/MMBtu
18-28	F11.3	Actual minemouth cost, period 2	cents/MMBtu
29-39	F11.3	Actual minemouth cost, period 3	cents/MMBtu

[a] AUSM sulfur categories are 12 minus the codes listed in codelist K.

Table B1-27
FILE EXIST FORMAT

This file contains data on period 1 production of each coal type. There is one record for every possible coal-type/region combination.

Column	Format	Contents	Unit/ Codelist
1-3	I3	Supply region	Codelist J
4-6	I3	Sulfur category	Codelist K
7-10	I3	HHV category	Codelist N
20-29	F10.3	Sulfur production	MMtons/year
30-39	F10.3	Deep production	MMtons/year

Note: EXIST is the only file in the coal module in which sulfur categories are not the reverse of codelist K.

Table B1-28

WASH1, WASH2, WASH3 FORMAT

This file consists of one section for each of 385 distinct supply region-sulfur category combinations. Data within each section are organized as follows:

Line Number	Column	Format	Contents	Unit/Codelist
1	1-3	I3	HHV category	Codelist N[a]
1	4-6	I3	Supply region	Codelist J[a]
1	7-9	I3	sulfur category of raw coal (k)	Codelist K[a,c]
1	10-12	I3	= 0 if raw coal does not exist = 1 if raw coal exists	
1	13-18	F6.3	Sulfur content of raw coal	lbs/MMBtu
Records 2-6 follow only if raw coal type k exists.				
2	1-110	11E10.3	Cost of processing one ton of raw coal to coal type m; value -1 is given if washing is not possible[b]	$/ton
3	1-110	11E10.3	Weight yield (tons of processed coal/tons of raw coal)[b]	fraction
4	1-110	11E10.3	Higher heating values[b]	Btu/lb
5	1-110	11E10.3	Ash content[b]	percent
6	1-110	11I10	Technical level of preparation	Codelist M[a]

Note: Sections are sorted by the following keys: supply region, sulfur category. These files are not used when EIA data are processed. WASH1 contains data for bituminous coals, WASH2 contains data for sub-bituminous coals, and WASH3 contains data for lignite coals.

[a] Codelists are specified in Appendix E of the AUSM system design document [7].

[b] There are (12-k) items. Item (m-k+ 1) is the property that pertains to washing raw sulfur category k to processed sulfur category m.

[c] AUSM sulfur categories are 12 minus the codes listed in codelist K.

1.5.2.3 **Coal Transportation Costs**. This information is read from input file CTRANS (assigned unit 7) the first time that UPCHAR is called and stored in the array TRANS. TRANS is indexed by the array INDEXT in order to rank the costs of shipping coal from suppliers to each demander. The format of CTRANS is shown in Table B1-29.

1.5.2.4 **Input Parameter File**. Execution control parameters are specified in file USERLC (assigned unit 8). These parameters are defined in Table B1-30.

1.5.2.5 **Cost File**. Least costs of delivered coal as well as characteristics of least cost coals are written to output file COST (assigned unit 1). This is the main output file generated by the coal allocation preprocessor. It contains information about the cheapest coals available to each demand region in each year of the simulation period. The format of file COST appears in Table B1-31.

1.5.2.6 **Intermediate File 1**. This output file, INTRM1 (assigned unit 3), saves the costs of delivering each coal type from every supply region to each demand region. INTRM1 is summarized in Table B1-32.

Table B1-29

FILE CTRANS FORMAT

Column	Format	Contents	Unit/Codelist
1-2	I2	demand region (j)	codelist I[a]
1-2	I2	supply region (i)	codelist J[a]
3-4	2X	filler	
15-24	E10.4	cost of shipping coal from i to j	$/ton

[a] Codelists are specified in Appendix E of the AUSM system design documentation [7].

Table B1-30

FILE USERLC FORMAT

Record	Format	Contents	Unit/Codelist
1	I2	trace indicator specifying coal type to trace	codelist K[a]
2	I2	coal price data set indicator 1 = AUSM data 2 = EIA data	
3	I2	number of years in simulation	
4	7I2	list of years in simulation (1980 = 1)	
5	I1	intermediate file requests 0 = no intermediate files 1 = generate file #1 2 = generate file #2 3 = generate file #1 and #2	
6	F5.3	transportation escalator #1	fraction
7	I2	year in which transportation escalator #1 takes effect	
8	F5,3	transportation escalator #2	fraction
9	I2	year in which transportation escalator #2 takes effect	
10	I1	Source of post-1980 coal prices 0 = use prices found on CPRICE 1 = generate post-1980 prices by escalating 1980 minemouth prices	
11	F4.3	annual price increase for western coals	fraction
12	F4.3	annual price increase for eastern coals	fraction
13	I1	washing scenario 0 = normal washing 1 = mandatory washing scenario in effect	
14	F4.3	minimum sulfur removal	fraction
15	F4.3	minimum process weight yield	fraction
16	F4.3	threshold sulfur removal	fraction

[a] Codelists are specified in Appendix E of the AUSM system design document [7].

Table B1-31

COST FILE FORMAT

Column	Format	Contents	Unit/Codelist
1-4	I4	year	
5-7	I3	demand region	codelist I[a]
8-10	I3	sulfur category	codelist K[a,b]
11-13	I3	HHV category	codelist N[a]
14-23	E10.4	least-delivered cost (LDC)	cents/MMBtu
24-25	I2	supplier of LDC coal	codelist J[a]
26-35	E10.4	HHV of LDC coal	Btu/pound
36-45	E10.4	ash contents of LDC coal	percent
46-47	I2	technical level of preparation of LDC coal	codelist M[a]
48-49	I2	raw coal type of LDC coal	codelist K[a]
50-59	E10.4	least-delivered cost of local coal (LDCL)	cents/MMBtu
60-61	I2	supplier of LDCL coal	codelist J[a]
62-71	E10.4	HHV of LDCL coal	Btu/pound
72-81	E10.4	ash content of LDCL coal	percent
82-83	I2	technical level of preparation of LDCL coal	codelist N[a]
84-85	I2	raw coal type of LDCL coal	codelist K[a]
86-95	E10.4	minemouth price of nationally selected coal	cents/MMBtu
96-105	E10.4	washing cost of nationally selected coal	cents/MMBtu
106-115	E10.4	transportation cost of nationally selected coal	cents/MMBtu

Note: The file contains a maximum of 15,840 data records, which represent unique information for up to ten years, 48 demand regions, 11 processed coal types, and 3 higher heating value categories. A delivered cost of "-1" indicates that no supplier produces the corresponding coal type.

[a] Codelists are specified in Appendix E of the AUSM system design document [7].

[b] AUSM sulfur categories are 12 minus the codes listed in codelist K.

1.5.2.7 **Intermediate File 2**. All feasible processed coal types are written to intermediate file 2 (INTRM2). This output file (assigned unit 4) is defined in Table B1-33.

1.5.3 Subprogram Summaries

Table B1-34 provides brief synopses of the 13 subroutines in LEASTC. The subroutines are presented in more detail below.

1.5.3.1 Subroutine COSTRD

Called by: UPCHAR.

Calls: None.

Arguments: PRICMM, HHVS.

Tasks: Sets the array of minemouth costs, PRICMM. COSTRD modifies PRICMM by substituting Green's actual minemouth costs in the first time period. A period 1 cost is interpolated between the actual period 1 cost and the period 3 cost. If the user-specified cost option is selected, this subroutine further modifies PRICMM by eliminating coals with insufficient reserves and production. Performs the minemouth cost adjustments outlined in Section 1.5.2.1. Finally, COSTRD escalates all period 1 costs at the eastern and western rates set on the parameter file.

Method: COSTRD first reads all data from the model minemouth cost file CPRICE (unit 21) into the array PRICMM. Data representing actual minemouth costs are then read from file GPRICE (unit 22). If the actual price paid is 0.0 (missing), the costs for that coal in PRICMM are also set to 0.0 for time periods 1 and 2. If the actual cost in the time period 1 is greater than zero, but the estimated cost in time period 3 is zero, that coal has a minemouth cost set to zero for all time periods (essentially, the coal is deleted). If both period 1 actual costs and period 3 estimated costs are greater than zero, the actual cost is substituted into the first period element of that coal in PRICMM. Period 2 estimated

Table B1-32
FILE INTRM1 FORMAT

Column	Format	Contents	Unit/Codelist
1-3	I3	year (y)	codelist J[a]
4-6	I3	supply region (i)	codelist I[a]
7-9	I3	demand region (j)	codelist K[a]
10-12	I3	processed coal type (m)	codelist K[a,b]
13-15	I3	raw coal type (k)	codelist K[a,b]
16-18	I3	HHV category (h)	codelist N[a]
19-28	E10.4	delivered cost of coal mkhijy	cents/MMBtu

Note: This file contains a maximum of 50,400 records, which represent the least cost at which each supplier can deliver each processed coal type to each demander in each of ten possible years.

[a] Codelists are specified in Appendix E of the AUSM system design document [7].

[b] AUSM sulfur categories are 12 minus the codes listed in codelist K.

Table B1-33
FILE INTRM2 FORMAT

Column	Format	Contents	Unit/Codelist
1-4	I4	year	
5-7	I3	processed coal type	codelist K[a,b]
8-10	I3	supply region	codelist J[a]
11-13	I3	HHV category	codelist N[a]
14-23	E10.4	HHV	Btu/lb
24-33	E10.4	preshipment price	cents/MMBtu
34-36	I3	raw coal type	codelist K[a]
37-39	I2	technical level of preparation	codelist M[a]

[a] Codelists are specified in Appendix E of the AUSM system design document [7].

[b] AUSM sulfur categories are 12 minus the codes listed in codelist K.

Table B1-34

SYNOPSIS AND CALLING SEQUENCE OF LEASTC SUBPROGRAMS

Subprogram	Synopsis	Calling Sequence
COSTRD	Reads minemouth price files and updates with actual price paid; escalates post-period 1 costs by escalating period 1 costs	COSTRD←UPCHAR ←OFFER←LEASTC
ELIM	Sorts washed coals and eliminates infeasible alternatives	ELIM←OFFER ←LEASTC
FWASH	Generates washing matrices under a given set of forced washing assumptions	FWASH←UPCHAR ←OFFER←LEASTC
IFIPS	Function; returns the FIPS code that corresponds to the order in which a state occurs in the FIPS sequence of the 48 contiguous states	IFIPS←LEASTC
LEASTC	Main program: supervises selection of least-cost coals; writes COST output file	
OFFER	Identifies least-delivered costs that supply regions can offer a processed coal type to each demand region	OFFER←LEASTC
READP	Reads input parameters; copies these parameters to least cost output file	READP←LEASTC
SELECT	Selects the supply region that offers a processed coal at the least cost to a specified demand region	SELECT←LEASTC
SELLOC	Selects the supply region that offers a local processed coal at the least cost to a specified demand region	SELLOC←LEASTC
UPCHAR	Updates coal characteristic variables to reflect current coal type; reads data files	UPCHAR←OFFER ←LEASTC
WASHER	Creates a set of dummy wash files on units 11-15 whenever the EIA data base is processed	WASHER←UPCHAR←OFFER ←OFFER←LEASTC

cost is calculated by interpolation.

Further adjustments are made if the user-specified price escalation option is in effect. Demonstrated reserves are read from file DEMBAS (unit 24). If a coal has reserves of less than 150 million tons in the first period, the period 1 cost is set to zero, ensuring that this coal will be eliminated (the escalation process calculates period 2 to NUMYRS costs as a multiple of period 1 cost. Data on production are then read from EXIST (unit 33). Surface and deep production figures are added. If the given coal has an annual production under 200,000 tons, the period 1 cost is again set to zero. After these modifications, all minemouth prices are escalated at a constant annual rate specified on the parameter file. Eastern and western coal may be escalated at different rates.

1.5.3.2 Subroutine LEASTC

Calls: IFIPS, OFFER, SELECT, SELLOC.

Task: Main subroutine; supervises selection of least-cost coals and writes cost output file.

Method: The control flow of this routine defines the logical flow of LEASTC. It is summarized as follows:

```
FOR each processed coal type DO
    FOR each HHV category DO
        FOR each year DO
            Identify least-cost coal alternatives across all supply regions (CALL OFFER);
            FOR each demand region DO
                Select least-cost coal delivery to current demand region (CALL SELECT);
                Select least-cost delivery of local coal to current demand region (CALL SELLOC);
            Write least-cost selections to COST file;
          END;
        END;
      END;
    END.
```

1.5.3.3 Subroutine ELIM

Called by: OFFER.

Calls: None.

Arguments:

ISUP - Supply region

MODE - HHV category

KTYPE - Processed coal type

IYR - Current year

ITRACE - Trace option

Task: Sorts coals of the current type and supply region in preparation for determining offers that can be made to demanders.

Method: Coals are ordered by increasing HHV. Next, any coal of rank i is eliminated if its pre-shipment cost is greater than the cost of the coal ranked i + 1. All remaining coals are written to intermediate file 2.

1.5.3.4 Subroutine FWASH

Called by: UPCHAR.

Calls: None.

Arguments: None.

Task: Transforms the existing wash file into a new file according to user-specified assumptions about forced washing. The forced-washing scenario is controlled by three variables in the parameter input files: SLPHRM, WTYLD, and THSLPH. Raw coal-processed coal paths are eliminated according to the following specifications:

1. A wash path is eliminated if a SLPHRM (minimum) fraction of sulfur is not removed from the raw coal.

2. If a removal of a SLPHRM fraction of sulfur would result in a processed weight yield of less than WTYLD, then the raw coal need be washed only so that the weight yield is equal to WTYLD.

3. If washing to a processed weight yield of WTYLD results in a threshold sulfur removal of less than THSLPH, then that coal is exempt from the washing requirement entirely.

If a washing path (including one from a raw coal to itself) is eliminated, the washing cost is set equal to -1.0, which is read by LEASTC as an impossible path. The finished wash matrices are written to units 31 (bituminous), 32 (sub-bituminous), or 33 (lignite).

Method: The objective here is to define which raw and processed coal types are to be excluded—that is, eliminated from the set of allowable processed coals that might be selected on the basis of economic considerations. One raw coal type is considered at a time. The cleanest (lowest sulfur) processed coal type obtainable by washing the raw coal is always set as allowable. If there is only one processed coal type, FWASH then moves to the next raw coal type. If more than one processed coal type is obtainable, the routine then examines the percentage of sulfur removed. If this percentage is less than the threshold removal fraction (THSLPH), all processed coals possible from the raw coal are set as allowable.

If the percentage removal is greater than the threshold, the weight yield and sulfur removal fraction of the cleanest processed coal are compared with the minimum weight yield and minimum sulfur removal fraction. If the weight yield is greater than the minimum and the sulfur removed is less than the minimum, only the cleanest coal type is allowed and all dirtier (higher sulfur) processed coal types are set as not allowable because their sulfur removal will also fall short of the minimum. If either of these conditions is not met, the next dirtiest processed coal type is examined. If the weight yield exceeds the minimum but the sulfur removal falls short of the minimum, this processed type and all dirtier process types are set as not allowable because they too will fail the same tests. If either the weight yield falls short or the sulfur removal exceeds the minimum, this type is considered allowable, and the next dirtiest processed type is examined. This last step is repeated until the raw coal type has been tested. See Figure B1-8, the flowchart for this routine.

1.5.3.5 Subroutine READP

Called by: LEASTC.

Calls: None.

Arguments: None.

Tasks:

1. Reads header information from the minemouth coal price input file and copies to LCHEAD.
2. Reads input parameters from file USERLC into labeled common.
3. Rewinds USERLC and copies to the least-delivered-cost output file.

Figure B1-8

FLOWCHART OF LEASTC MAIN PROGRAM

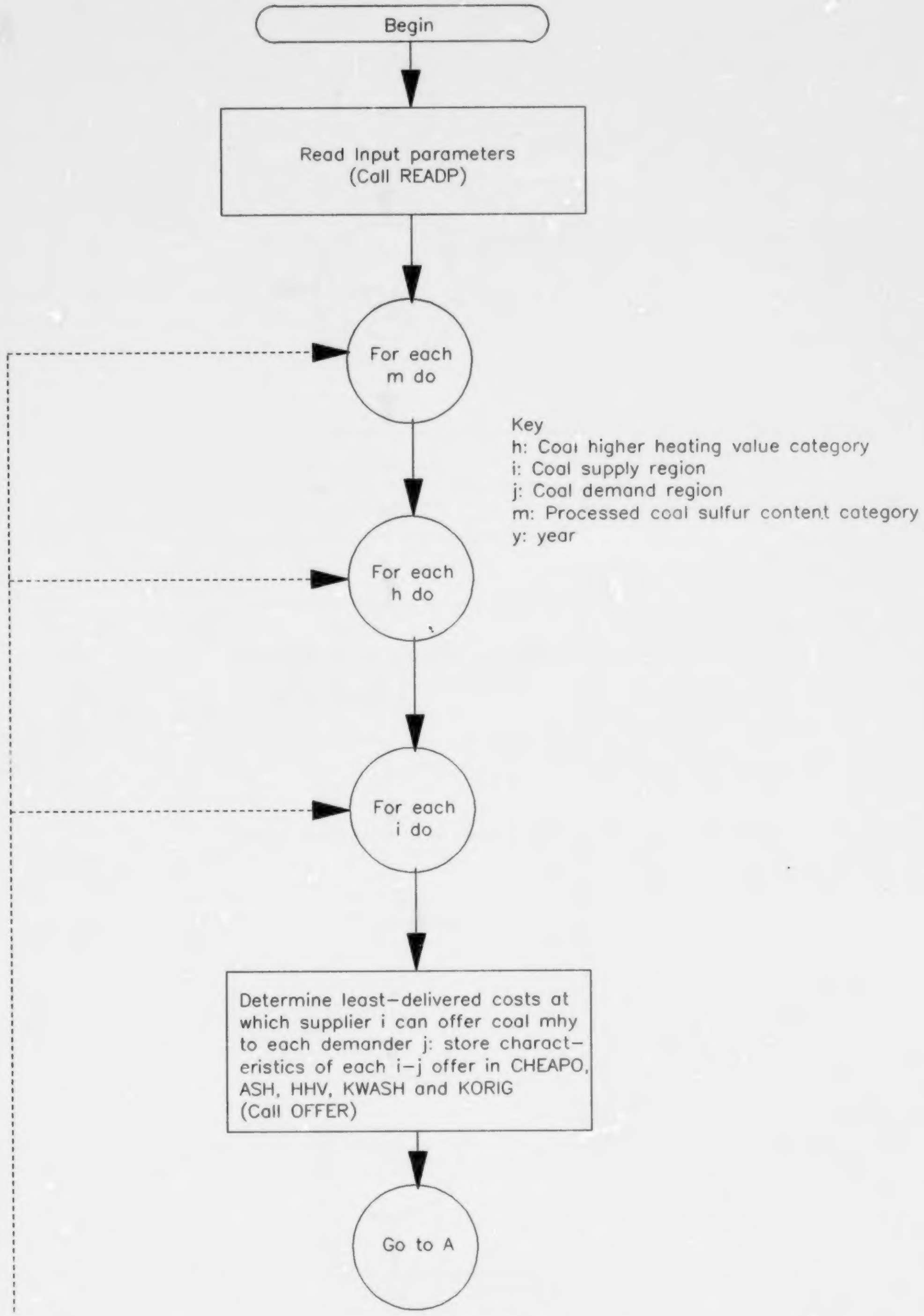
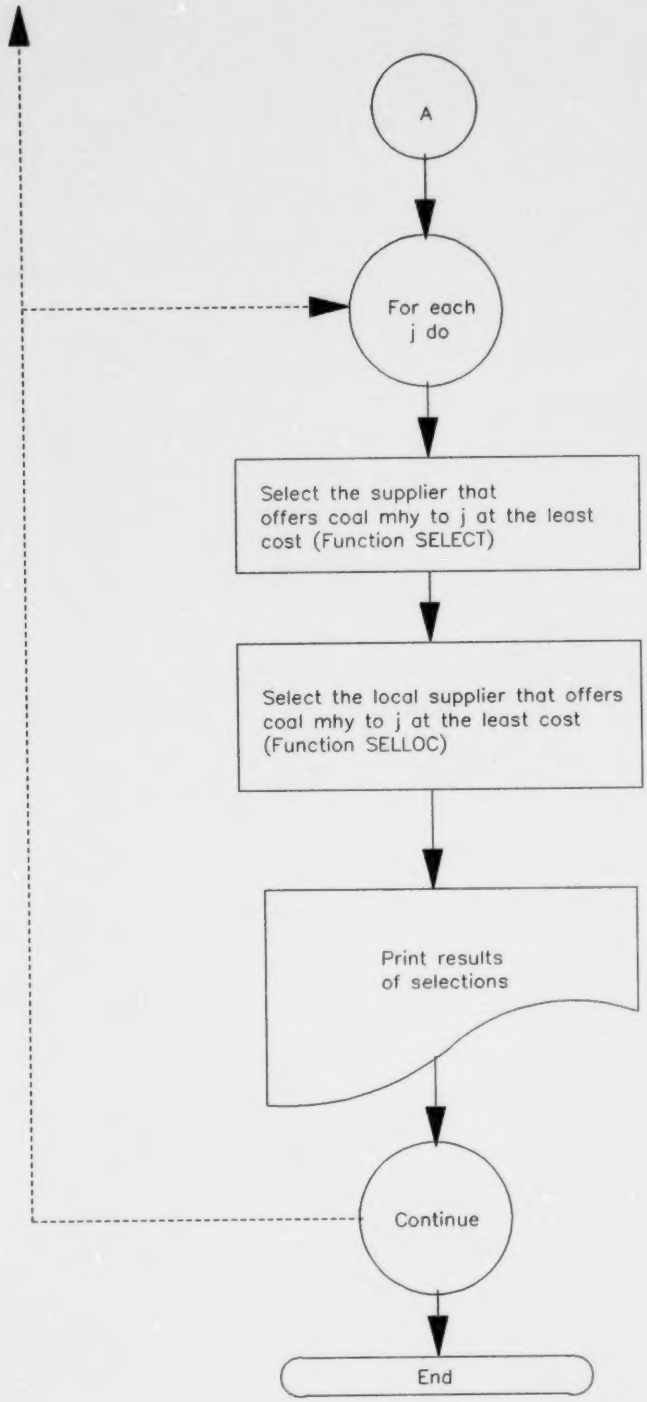

Begin
Read Input parameters
(Call READP)
For each m do
For each h do
For each i do
Determine least-delivered costs at which supplier i can offer coal mhy to each demander j: store characteristics of each i-j offer in CHEAPO, ASH, HHV, KWASH and KORIG
(Call OFFER)
Go to A
Key
h: Coal higher heating value category
i: Coal supply region
j: Coal demand region
m: Processed coal sulfur content category
y: year

Figure B1–8 (contd.)


A
For each j do
Select the supplier that offers coal mhy to j at the least cost (Function SELECT)
Select the local supplier that offers coal mhy to j at the least cost (Function SELLOC)
Print results of selections
Continue
End

1.5.3.6 Subroutine WASHER

Called by: UPCHAR.

Calls: None.

Arguments: PRICMM (coal price array), HHVS (higher heating value array).

Tasks: Generates a dummy wash file for use with EIA coal price data. Since EIA data have washing costs included as part of the total price, there is no separate wash file for this data set. It is necessary to create one since LEASTC always expects washing data. The resulting output file assumes that: (1) there is no shrinkage in washing; (2) there is no cost for washing (since washing is already included in the coal price); and (3) the coal type cannot be washed to a cleaner type.

Method: The price file is scanned. If a coal is not present, one record is written containing the higher heating value code, sulfur category, supply region code, and IFOUND, set equal to zero. If the coal is found, the above record is written, with IFOUND = 1. A wash cost record is written, with the cost for the raw coal set equal to zero and the cost for all cleaner coals set equal to -1; this eliminates all possible washing paths. A weight yield record is written, with yield for the raw coal equal to 1. Higher heating values, ash content, and technical level of preparation for the raw coal are written to the following three records.

1.5.3.7 Subroutine OFFER

Called by: LEASTC.

Calls: UPCHAR.

Arguments:

KTYPE - Processed coal type

MODE - HHV category

IYR - Current year

CHEAPO - Matrix of least-delivered costs from all suppliers to all demanders

HHV - Matrix of HHVs corresponding to CHEAPO

ASH - Matrix of ash contents corresponding to CHEAPO

KWASH - Matrix of technical levels of preparation corresponding to CHEAPO

KORIG - Matrix of raw coal type corresponding to CHEAPO

ITRACE - Trace option

COMPMM - Matrix of minemouth prices of nationally selected coals

COMPTR - Matrix of transportation costs of nationally selected coals

COMPW - Matrix of washing costs of nationally selected coals

Tasks: Finds the cheapest delivered prices at which each supplier can offer the current processed coal type to each demander; writes these choices to intermediate file 1.

Method: The following steps are performed for each supply region:

1. Update coal characteristic variables with data corresponding to current coal type/supply region (CALL UPCHAR).

2. Index all possible coals by increasing HHV. Eliminate infeasibles (CALL ELIM).

3. Find the best offers of the current coal type that the current supplier can make to demanders whose shipping costs fall within a critical range.

4. Fill in characteristics of coal offers made to demanders.

5. If some demanders have not made offers, go to step 3.

6. **Write all offers to intermediate file 2.**

1.5.3.8 Subroutine SELECT

Called by: LEASTC.

Calls: None.

Arguments:

JDEM - **Demand region identifier corresponding to the order in which a state occurs in the FIPS sequence**

CHEAPO - **Matrix of least-delivered costs from all suppliers to all demanders**

IWIN - **Supply region offering JDEM the current coal type at the least cost**

Task: **Sets IWIN equal to the supply region offering JDEM the current coal type at the least cost.**

Method: **Scans CHEAPO to find the best offer that can be made to JDEM.**

1.5.3.9 Subroutine SELLOC

Called by: LEASTC.

Calls: None.

Arguments:

JDEM - **Demand region identifier corresponding to the order in which a state occurs in FIPS sequence**

CHEAPO - **Matrix of least-delivered costs from all suppliers to all demanders**

IWIN - **Supply region offering JDEM the local coal of the current coal type at the least cost**

Task: **Sets IWIN equal to the supply region offering JDEM the least-cost local coal.**

Method: This routine scans CHEAPO to find the best offer that can be made. Local suppliers are matched to demanders in array MAP, which currently defines "local" as in the same state as the demand region. Alternative definitions may be implemented by altering MAP.

1.5.3.10 Subroutine UPCHAR

Called by: OFFER.

Calls: WASHER, USRESC, FWASH, COSTRD.

Arguments:

KTYPE - Processed sulfur category
MODE - HHV category
IYR - Current year
JSUP - A supply region
ITRACE - Trace option

Task: Identifies the characteristics of all coals of the current coal type. In this context, the coal type is identified as the combination of processed sulfur category, HHV category, year, and supplier. All data files are read in this routine.

Method: The control flow of this data access routine is summarized in Section 1.5.4.

1.5.4 Flowcharts of Principal Subroutines

Flowcharts of the principal LEASTC subroutines are found in Figures B1-9 through B1-12.

1.5.5 Variable Definitions

Tables B1-35 and B1-36 summarize the variables used in LEASTC.

Figure B1–9
SUBROUTINE COSTRD FLOWCHART

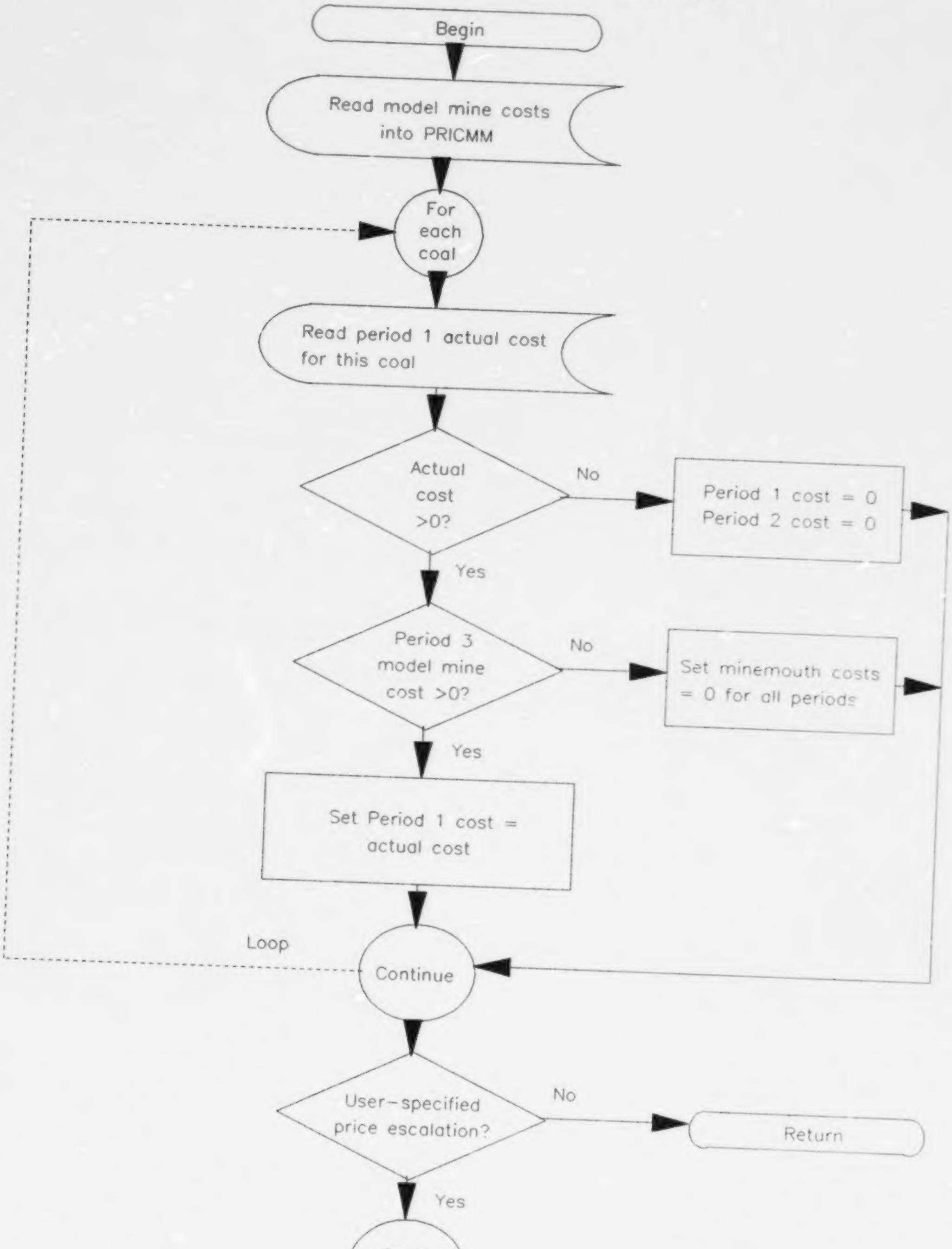

Begin
Read model mine costs into PRICMM
For each coal
Read period 1 actual cost for this coal
Actual cost >0?
No
Period 1 cost = 0
Period 2 cost = 0
Yes
Period 3 model mine cost >0?
No
Set minemouth costs = 0 for all periods
Yes
Set Period 1 cost = actual cost
Loop
Continue
User–specified price escalation?
No
Return
Yes
Go to A

Figure B1–9 (contd.)

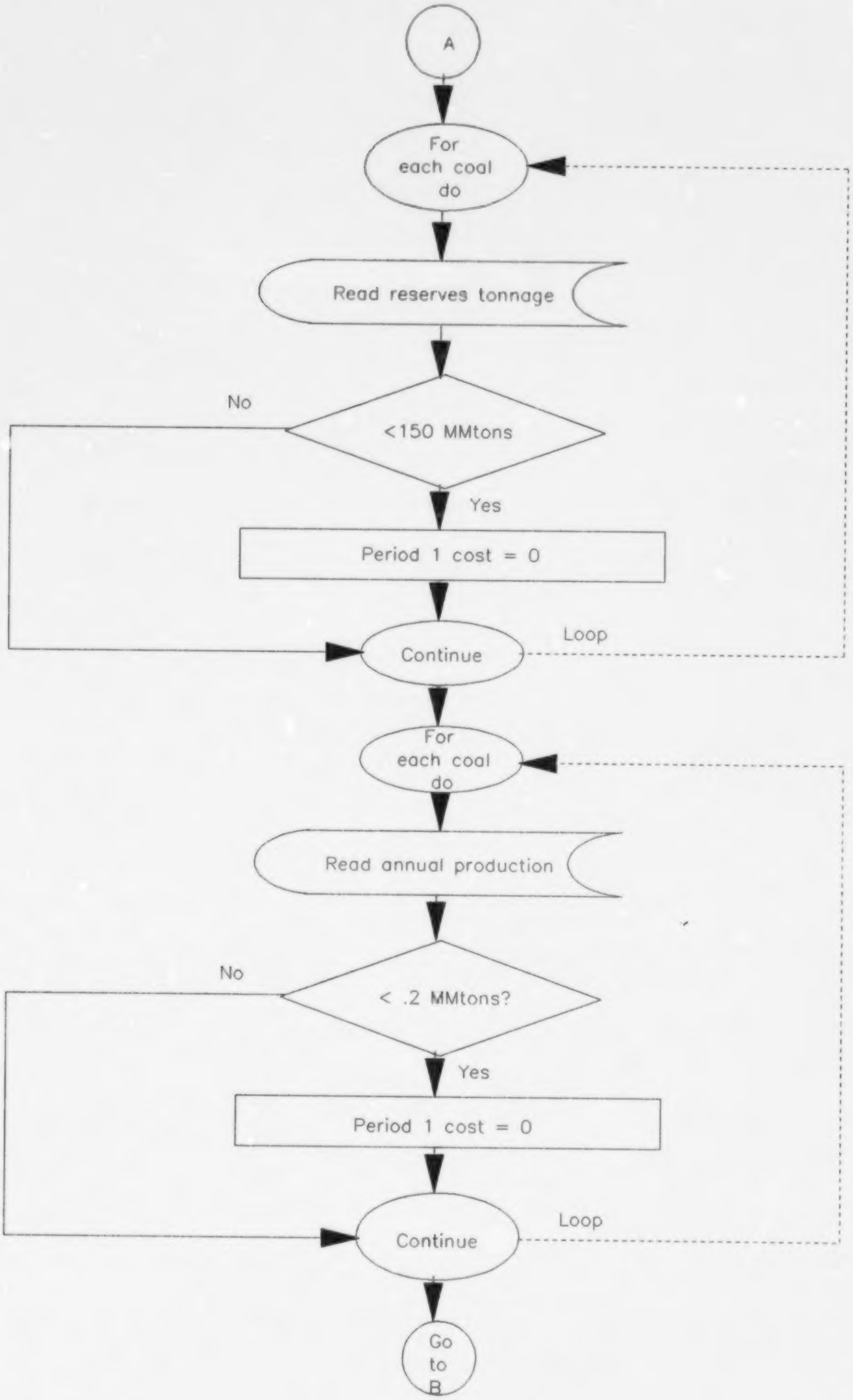


Figure B1–9 (contd.)

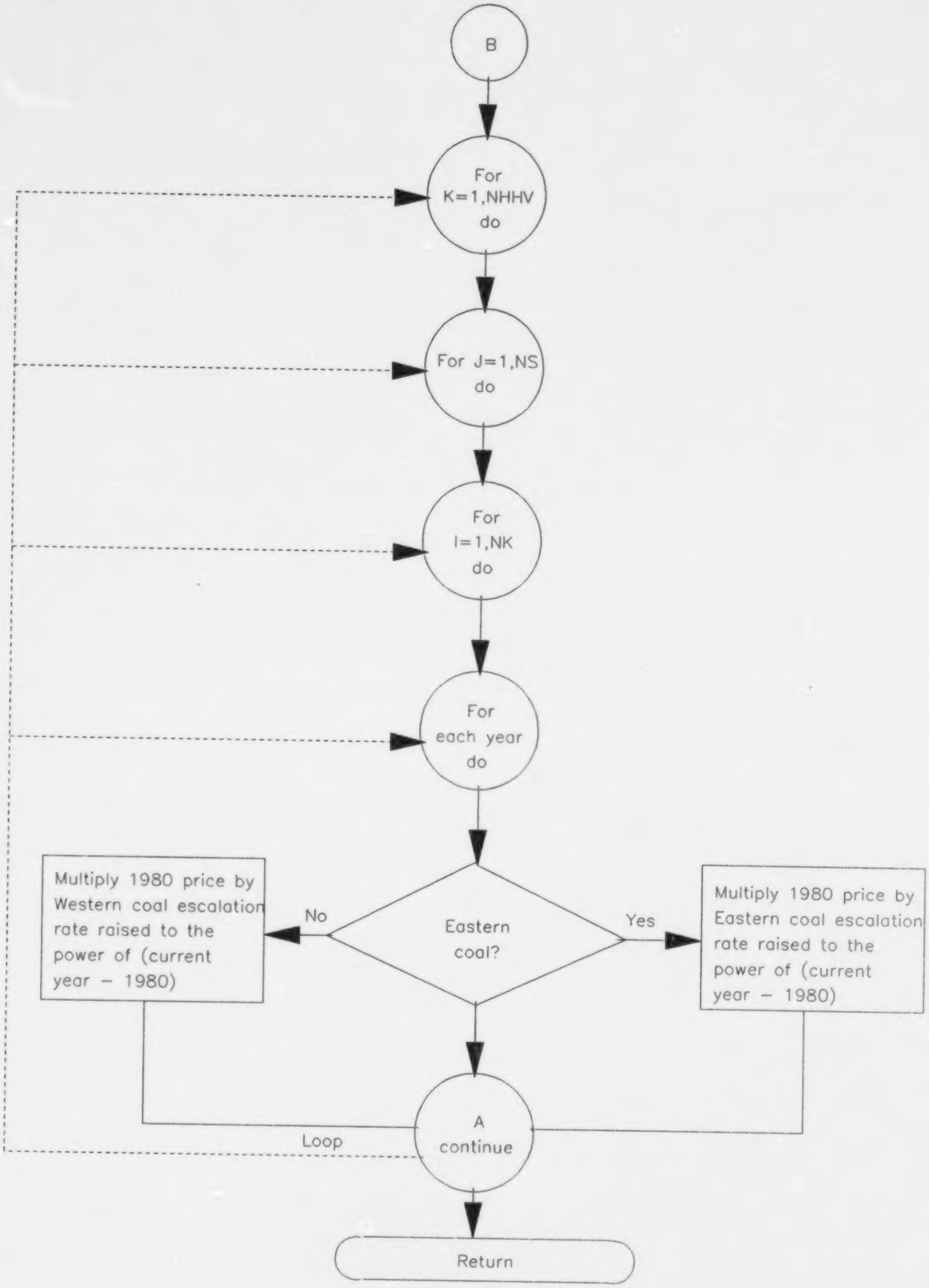
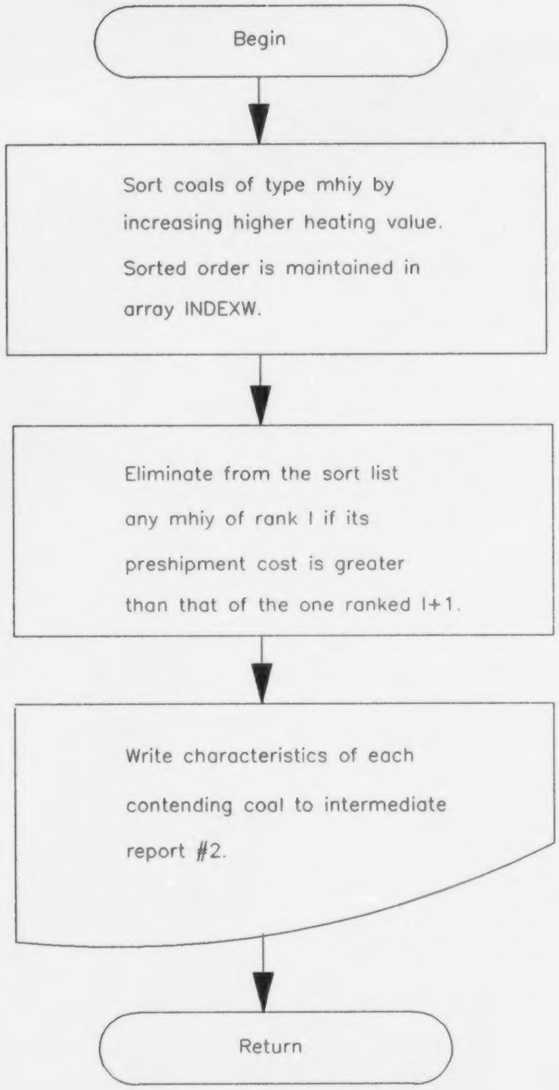

B
For K=1,NHHV do
For J=1,NS do
For I=1,NK do
For each year do
Eastern coal?
No
Yes
Multiply 1980 price by Western coal escalation rate raised to the power of (current year – 1980)
Multiply 1980 price by Eastern coal escalation rate raised to the power of (current year – 1980)
A continue
Loop
Return

Figure B1-10
SUBROUTINE ELIM FLOWCHART



Key:

h: Coal higher heating value

i: Coal supply region

m: Processed coal sulfur category

y: Year

Begin
Sort coals of type mhiy by increasing higher heating value. Sorted order is maintained in array INDEXW.
Eliminate from the sort list any mhiy of rank I if its preshipment cost is greater than that of the one ranked I+1.
Write characteristics of each contending coal to intermediate report #2.
Return

Figure B1-11
SUBROUTINE OFFER FLOWCHART

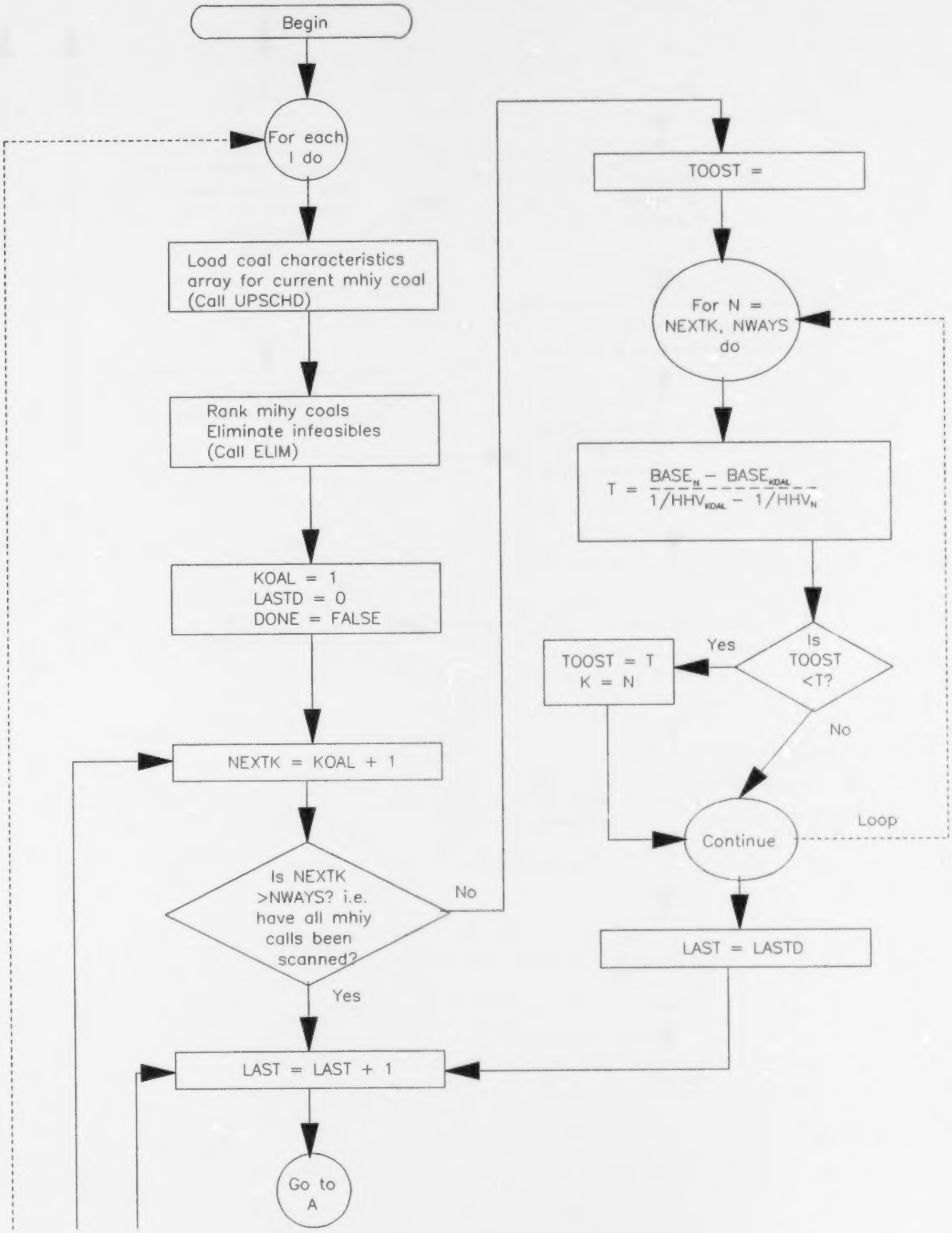

Begin
For each I do
Load coal characteristics array for current mhiy coal (Call UPSCHD)
Rank mihy coals Eliminate infeasibles (Call ELIM)
KOAL = 1
LASTD = 0
DONE = FALSE
NEXTK = KOAL + 1
Is NEXTK >NWAYS? i.e. have all mhiy calls been scanned?
No
Yes
LAST = LAST + 1
Go to A
TOOST =
For N = NEXTK, NWAYS do
$T = \frac{BASE_N - BASE_{KOAL}}{1/HHV_{KOAL} - 1/HHV_N}$
Is TOOST <T?
Yes
No
TOOST = T
K = N
Continue
Loop
LAST = LASTD

Figure B1−11 (contd.)

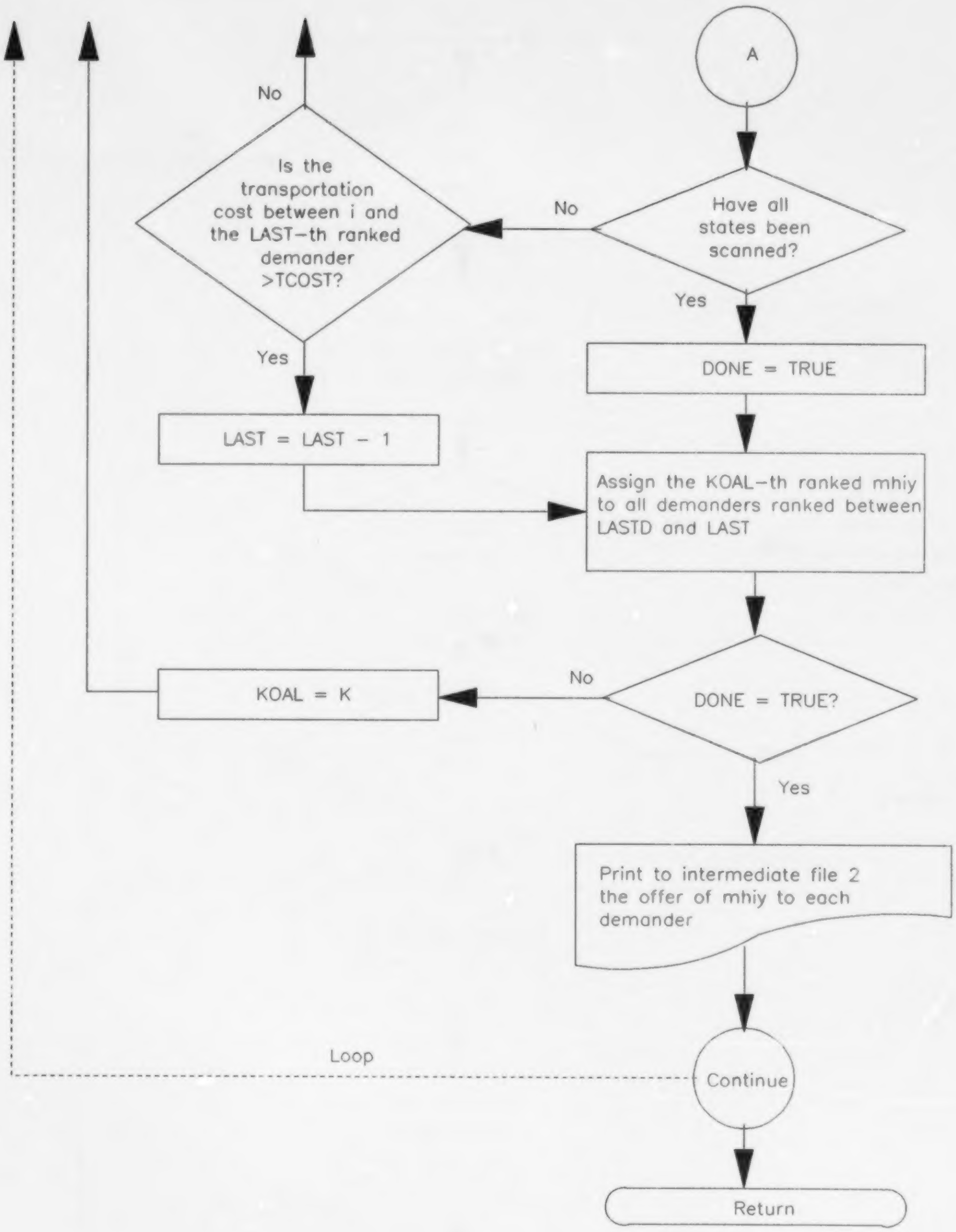

A
Have all states been scanned?
No
Is the transportation cost between i and the LAST−th ranked demander >TCOST?
No
Yes
LAST = LAST − 1
Yes
DONE = TRUE
Assign the KOAL−th ranked mhiy to all demanders ranked between LASTD and LAST
DONE = TRUE?
No
KOAL = K
Yes
Print to intermediate file 2 the offer of mhiy to each demander
Loop
Continue
Return

Figure B1-12
SUBROUTINE UPCHAR FLOWCHART

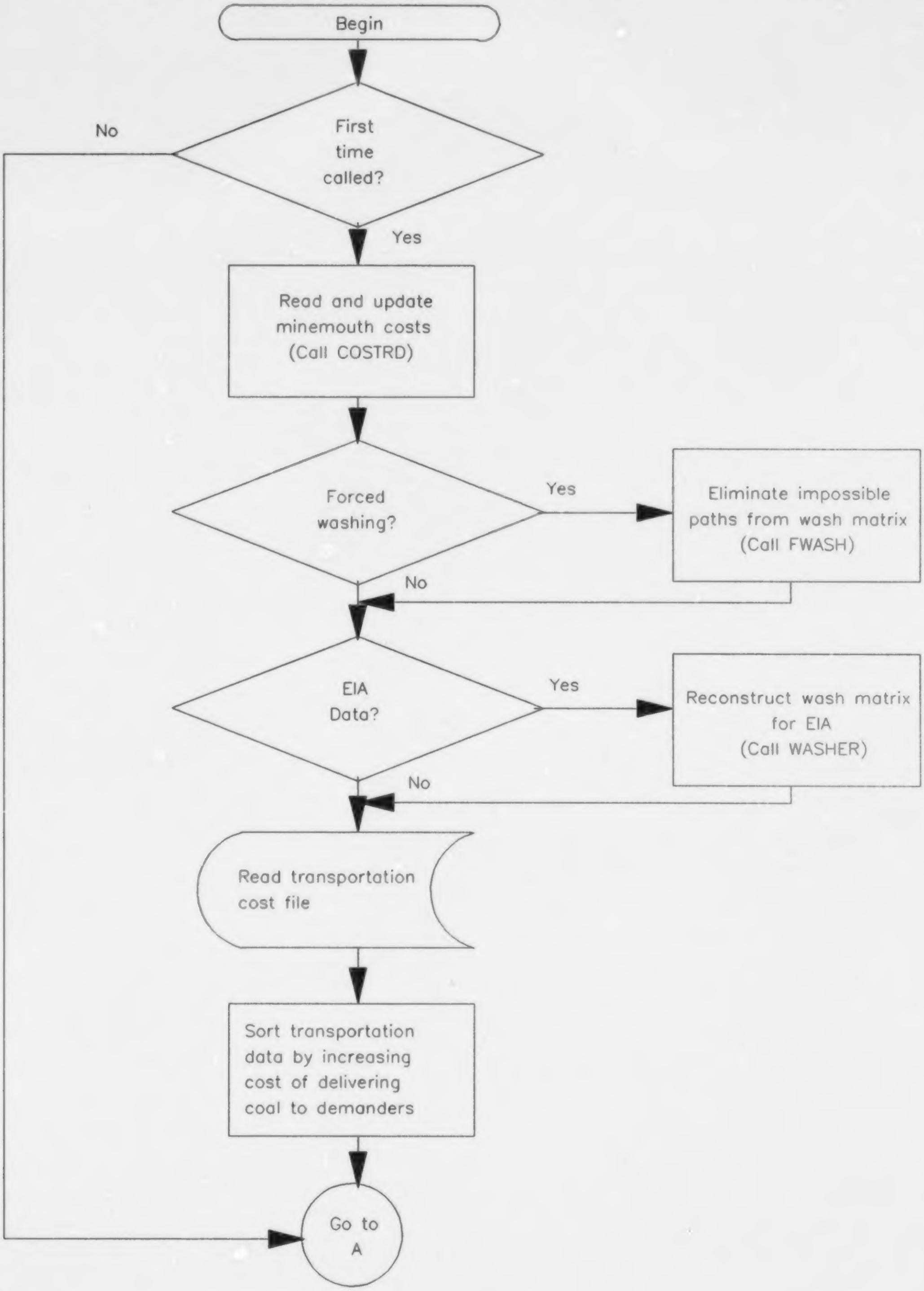

Begin
First time called?
No
Yes
Read and update minemouth costs (Call COSTRD)
Forced washing?
Yes
Eliminate impossible paths from wash matrix (Call FWASH)
No
EIA Data?
Yes
Reconstruct wash matrix for EIA (Call WASHER)
No
Read transportation cost file
Sort transportation data by increasing cost of delivering coal to demanders
Go to A

Figure B1−12 (contd.)

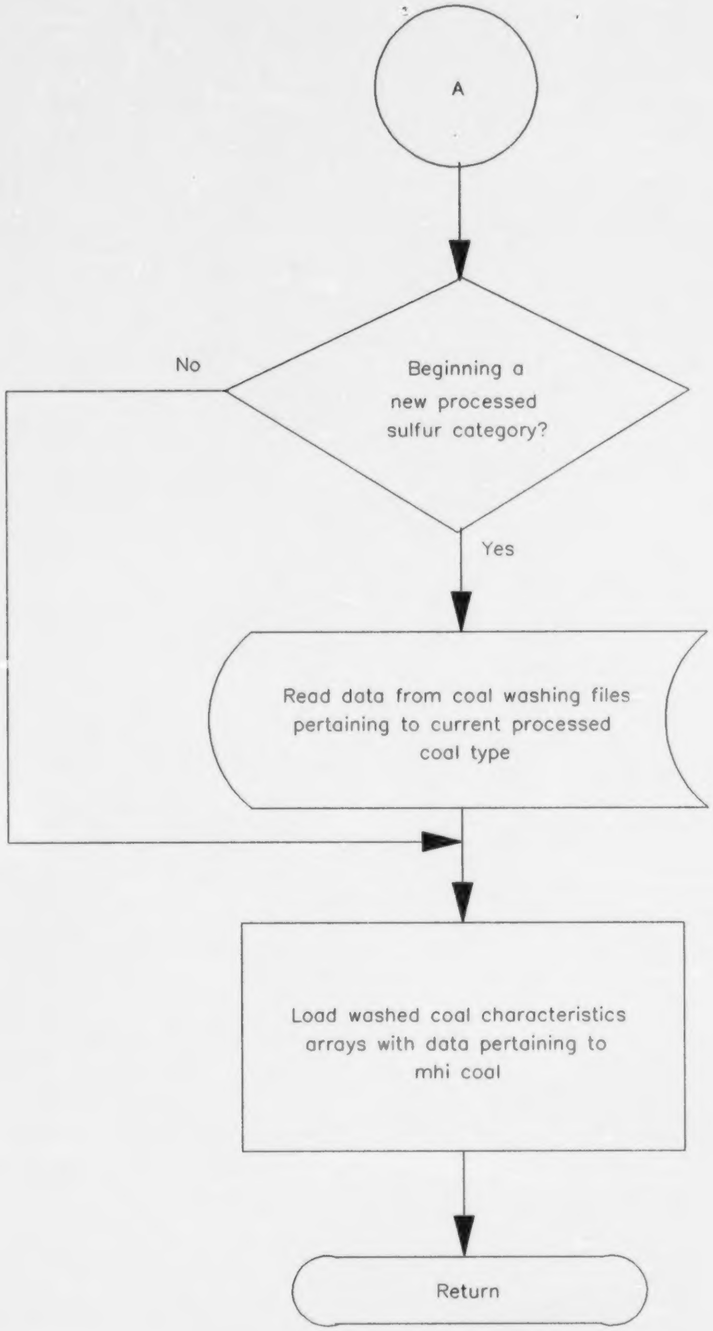

A
No
Beginning a new processed sulfur category?
Yes
Read data from coal washing files pertaining to current processed coal type
Load washed coal characteristics arrays with data pertaining to mhi coal
Return

Table B1-35
LEASTC VARIABLE DESCRIPTIONS

Variable	Unit	Description
ARRAY	alphanumeric	Stores price file and parameter file header information before copying to cost output file
ASH	percent	Ash contents of all least cost mby coals; indexed by i,j
ASHW	percent	Ash contents of all mh coals; indexed by i
BASEW	$/MMBtu	Preshipment costs of all mby coals; indexed by i
BASMMP	$/MMBtu	Minemouth price of all mbiy coals; values for washed coals are scaled by a weight yield factor, SHRINK
CHEAPO	cents/MMBtu	Least costs of all mby coals; indexed by i,j
COMPMM	cents/MMBtu	Minemouth component of least costs of all mby coals; indexed by i,j
COMPTR	cents/MMBtu	Transportation component of least costs of all mby coals; indexed by i,j
COMPWS	cents/MMBtu	Processing component of least costs of all mby coals; coals; indexed by i,j
COST	$/ton of raw coal	Washing costs of current coal types
COSTW	$/ton of raw coal	Washing costs of all mh coals; indexed by i
CURCAT	lb/MMBtu	Contains midpoint sulfur content of current and cleaner coals
DC	cents/MMBtu	Least delivered cost of any mbjy coal
DCLOCL	cents/MMBtu	Least delivered cost of any local mbjy coal
DONE		Flags whether an mbiy assignment has been made to all demanders
ESTESC		Price escalator for eastern coals computer as current year (1980)
EXPON		Computed as current year (1980); used in calculation of user specified price escalations
FORMAT		Execution time format specifier; used for reading coal washing data

Table B1-35 (contd.)

Variable	Unit	Description
H	Btu/lb.	Temporary storage for HHV
HHV	Btu/lb.	HHV of all least cost mh coals; indexed by i,j
HHVS	Btu/lb.	HHV of all ik coals
ICESC		User-specified price escalation flag
ID		Result of mapping FIPS state code into IDMAP
IDMAP		Array used to map state codes into an index between 1 and 48
IFND		Array storing current values of supply region sulfur category HHV and availability from washing file
IFOUND		Value read from coal washing files: = 1 if the current ik coal exists = 0 otherwise
IMARK		Stores integer output values in WASHER
INDEX	codelist I	Used to convert 1-48 demand region codes to FIPS codes
INDEXT		Sorted order of transportation costs stored in array TRANS
INDEXW		Sorted order of coals whose costs are stored in array COSTW (,i)
ITRACE		Scenario variable; specifies which processed sulfur category to trace
ITYR1		Effective year, transportation escalator #1
ITYR2		Effective year, transportation escalator #1
IWASH		Forced washing flag: 1 = forced washing option in effect 0 = otherwise
IWRITE		Scenario variable; specifies which intermediate files to generate

Table B1-35 (contd.)

Variable	Unit	Description
IYR		Current year in simulation
KOAL		Indexes an mhiy coal assigned to a group of demanders
KORIG	Codelist K	Specifies raw sulfur categories of least cost mhy coals offered by each supplier to each demander
KRAW	Codelist K	Specifies raw sulfur category of mhy coals offered to each demander; indexed by j
KSOURC	Codelist K	Specifies raw sulfur category of all least cost mh coals; indexed by i,j
KTYPE	Codelist K	Current processed sulfur category
KWASH	Codelist M	Specifies level of preparation of all least cost mh coals; indexed by i,j
KWASHW	Codelist M	Level of preparation of five best coals available for each supplier
LAST		First in a group of demanders being assigned an mhiy coal
LASTD		Last in a group of demanders being assigned an mhiy coal
LISTYR	years	List of years for which least-delivered costs are generated
MAP	Codelist J	Map of demand regions to local supply regions
MODE	Codelist N	HHV category
NCAT		Maximum number of possible washing paths
NEXTK		Ordinal of the coal next in rank after KOAL
NHHV		Number of HHV categories
NS		Number of SO_2 categories
NK		Number of supply categories
NUMYRS		Number of years for which least-cost data are generated
NWAYS		Number of ways of achieving the current mhi coal

Table B1-35 (contd.)

Variable	Unit	Description
NWAYSO		Number of ways of achieving the current mh coal in any supply region; indexed by i
OUTFLE		Variable output file specification
POSWSH	cents/MMBtu	Stores washing paths possible under forced washing scenario
PRICMM	cents/MMBtu	Minemouth prices of raw coals; indexed by k,i,h,y
RAWSLF	lb/MMBtu	Sulfur content of raw coal
RMARK	real	Stores real output values in WASHER
SCAT	lb/MMBtu	Contains midpoint sulfur content of all AUSM sulfur categories
SHRINK	tons of processed coal/tons of raw coal	Weight yield from coal processing
SLPHRM	fraction	Proportion of sulfur that must be removed in forced washing
T		Calculated intersection of two coals plotted on a preshipment cost, transportation cost grid
TCOST	$/ton	Critical transportation cost at which it becomes less costly to ship one mhiy coal than a lower ranked mhiy coal
TESC	fraction	Transportation escalator
THSLPH	fraction	Threshold sulfur removal under forced washing read from USERLC
TR		Temporary storage for TRANS
TRANS	$/ton	Cost of shipping coal from any supplier to any demander; indexed by j,i
TRESC1	fraction	Transportation escalator #1
TRESC2	fraction	Transportation escalator #2
WCOST	$/ton	Array of wash costs for raw coal k

Table B1-35 (contd.)

Variable	Unit	Description
WSTESC	percent	Annual price increase for western coals under user-specified price escalation
WTYLD	fraction	Minimum process weight under forced washing

Table B1-36
LEASTC VARIABLE INFORMATION

Variable	Type	Dimension	Unit	Storage Location	Accessed by
ARRAY	alphanumeric	20			READP
ASH	real	35,48	percent	argument	LEASTC,OFFER
ASHW	real	5,35	percent	/CHARS/	ELIM,OFFER,UPCHAR
BASEW	real	5,35	$/MMBtu	/CHARS/	ELIM,OFFER,UPCHAR
BASMMP	real	5	$/MMBtu	/CHARS/	ELIM,OFFER,UPCHAR
CHEAPO	real	35,48	cents/MMBtu		LEASTC,OFFER,SELECT,SELLOC
COMPMM	real	35,48	cents/MMBtu		LEASTC,OFFER,SELECT,SELLOC
COMPTR	real	35,48	cents/MMBtu		LEASTC,OFFER,SELECT,SELLOC
COMPWS	real	35,48	cents/MMBtu		LEASTC,OFFER,SELECT,SELLOC
COST	real		$/raw ton		FWASH
COSTW	real	5,35	$/raw ton		UPCHAR
CURCAT	real	11	lb/MMBtu		FWASH
DC	real		cents/MMBtu		LEASTC
DCLOCL	real		cents/MMBtu		LEASTC
DONE	logical				OFFER
ESTESC	real		fraction	/PARAMS/	USRESC
EXPON	real				USRESC
FORMAT	real	4			UPCHAR
H	real		Btu/lb	UPCHAR	
HHV	real	35,48	Btu/lb	argument	LEASTC,UPCHAR
HHVS	real	35,48	Btu/lb		UPCHAR,WASHER
ICESC	integer			/PARAMS/	USRESC
ID	integer		codelist I		UPCHAR

Table B1-36 (contd.)

Variable	Type	Dimension	Unit	Storage Location	Accessed by
IDMAP	integer	56			UPCHAR
IFND	real	4			FWASH
IFOUND	integer				UPCHAR
IMARK	integer	3			WASHER
INDEX	integer	48	codelist I		IFIPS
INDEXT	integer	48,35		/CHARS/	ELIM,OFFER,UPCHAR
INDEXW	integer	5		/CHARS/	ELIM,OFFER,UPCHAR
ITRACE	integer				LEASTC,ELIM,OFFER,UPCHAR
ITYR1	integer			/PARAMS/	UPCHAR
ITYR2	integer			/PARAMS/	UPCHAR
IWASH	integer			/PARAMS/	UPCHAR
IWRITE	integer				LEASTC,ELIM,OFFER,UPCHAR
IYR	integer			argument	LEASTC,ELIM,OFFER,UPCHAR
KOAL	integer				OFFER
KORIG	integer	35,48	codelist K	argument	OFFER,UPCHAR
KRAW	integer	48	codelist K		OFFER
KSOURC	integer	5,35	codelist K	/CHARS/	ELIM,OFFER,UPCHAR
KTYPE	integer		codelist K	argument	ELIM,OFFER,UPCHAR
KWASH	integer	35,48	codelist M	argument	LEASTC,OFFER
KWASHW	integer	5,35	codelist M	/CHARS/	ELIM,OFFER,UPCHAR
LAST	integer				OFFER
LASTD	integer				OFFER
LISTYR	integer	11	year	/YEARS/	LEASTC,UPCHAR
MAP	integer	2,48	codelist J		SELLOC

Table B1-36 (contd.)

Variable	Type	Dimension	Unit	Storage Location	Accessed by
MODE	integer		codelist N	argument	LEASTC,ELIM,OFFER,UPCHAR
NCAT	integer				FWASH
NHHV	integer			/PARAMS/	OFFER
NEXTK	integer				OFFER
NK	integer			/PARAMS/	LEASTC
NUMYRS	integer			/YEARS/	LEASTC,UPCHAR
NS	integer			/PARAMS/	OFFER
NWAYS	integer			/CHARS/	ELIM,OFFER,UPCHAR
NWAYSO	integer	35		/CHARS/	UPCHAR
OUTFLE	integer				FWASH
POSWSH	real	11	cents/MMBtu		FWASH
PRICMM	real	11,35,3,11	cents/MMBtu		UPCHAR
RAWSLF	real		lb/MMBtu		FWASH
RMARK	real	3			WASHER
SCAT	real	11	lb/MMBtu		FWASH
SHRINK	real		tons of processed coal/tons of raw coal		UPCHAR
SLPHRM	real		fraction	/PARAMS/	FWASH
T	real				OFFER
TCOST	real		$/ton		OFFER
TESC	real		fraction		UPCHAR
THSLPH	real		fraction		READP,ELIM
TR	real		$/ton		UPCHAR

Table B1-36 (contd.)

Variable	Type	Dimension	Unit	Storage Location	Accessed by
TRANS	real	48,35	$/ton		ELIM,OFFER,UPCHAR
TRESC1	real		fraction	/PARAMS/	UPCHAR
TRESC2	real		fraction	/PARAMS/	UPCHAR
WCOST	real	11	$/ton	/PARAMS/	
WSTESC	real		percent	/PARAMS/	FWASH,USRESC
WTYLD	real		fraction	/PARAMS/	FWASH

1.6 Least-Cost Output Reformatting (Program MAKE6)

The output from LEASTC is not suitable for use in subsequent modules, and therefore, must be reformatted, as described in the AUSM System Design Document [7]. This reformatting is done by program MAKE6. MAKE6 also overwrites the 1980 cost with the actual price paid and interpolates a value for 1985 based on the actual 1980 price and the 1990 cost reported from LEASTC.

MAKE6 reads input parameters from unit 5 (standard input) and reads least-delivered cost data from COST (unit 20). COST is assumed to be in order by the following keys:

1) state
2) HHV category
3) coal sulfur category
4) year.

MAKE6 produces two output files, E6ALL and E6LOC, with identical formats. E6ALL contains cost data for the cheapest coal produced nationally. E6LOC contains cost data for the cheapest locally produced coal when it is available. National data is entered for demand regions that do not produce coal. The subroutine, ERROR, writes an error message when not formatted correctly.

1.6.1 Central Algorithms and Basic Assumptions

MAKE6 first copies the series of parameters from LCHEAD to E6ALL and E6LOC. A description of these parameters may be found in the E6 file description. Following the input parameters, 10 records are written for each demand region. Least-delivered costs for the first period are updated before being written to E6ALL and E6LOC. Before processing COST, MAKE6 first reads actual prices paid in each demand region for each coal type. These prices are read from file DEL80 and are stored in array P1980. When data for each demand region are written to the E6 files, P1980 is checked for the presence of a period 1 price. If such a price exists for a given coal type, that price is substituted for the least-delivered cost. Period 2 costs are then calculated by interpolation of period 1 and period 3 data. If P1980 contains no price (i.e., the particular array element is equal to minus 1), no action is taken. If the coal does not exist in the LEASTC output file COST, no action is taken. The first record contains the state FIPS code;

the second contains least-delivered costs for each coal. The record is sorted by coal type and year. Assuming seven simulation years, this record is 231 words long for AUSM data and 280 words long for EIA data. The third record contains annual price increases for each coal type and year. Records 4-10 contain data on the characteristics of each least-cost coal. One record represents one year.

1.6.2 Data Handling

All data are written using unformatted WRITE statements. MAKE6 processes one demand region at a time. Within each record, one record, from COST, representing one coal-type year combination is read. The information on cost and characteristics is transferred to several arrays that are dimensioned by year and coal type. As the data are sorted by state, each array is filled with all the information for one state. A marker, IFIPS, is set equal to the current state code. When a record with a different FIPS code is read, all the data are written to E6ALL and E6LOC. IFIPS is set equal to the new FIPS code, and the process is repeated. Details are given in Figure B1-13.

1.6.2.1 **Input Parameters File**. Input directives (assigned unit 5) are standard. MAKE6 reads three input parameters. See Table B1-37 for the file definitions.

1.6.2.2 **Cost File**. The format of COST (assigned unit 20) is described in the documentation for LEASTC (Section 1.5.2.5).

1.6.2.3 **E6ALL and E6LOC**. E6ALL (assigned unit 22) and E6LOC (assigned unit 24) both have identical formats. There are 25 records of header information on the E6 files. The format of these files appears in Table B1-38.

1.6.2.4 **DEL80 (Unit 7)**. DEL80 contains data on actual prices paid. The format appears in Table B1-39.

1.6.3 Subroutine Description.

MAKE6 has one subroutine, ERROR. When the input parameter file is not formatted correctly, ERROR writes an error message.

Figure B1-13

PROGRAM MAKE6 FLOWCHART

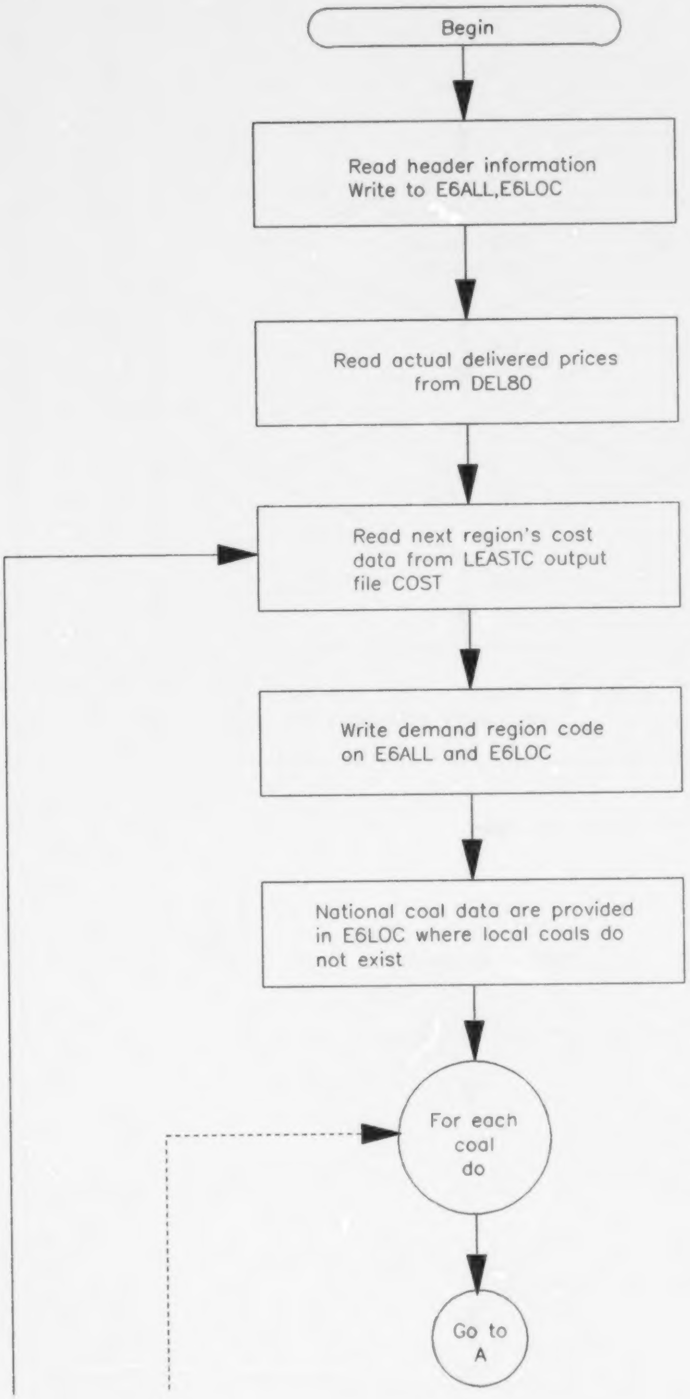


Figure B1–13 (contd.)

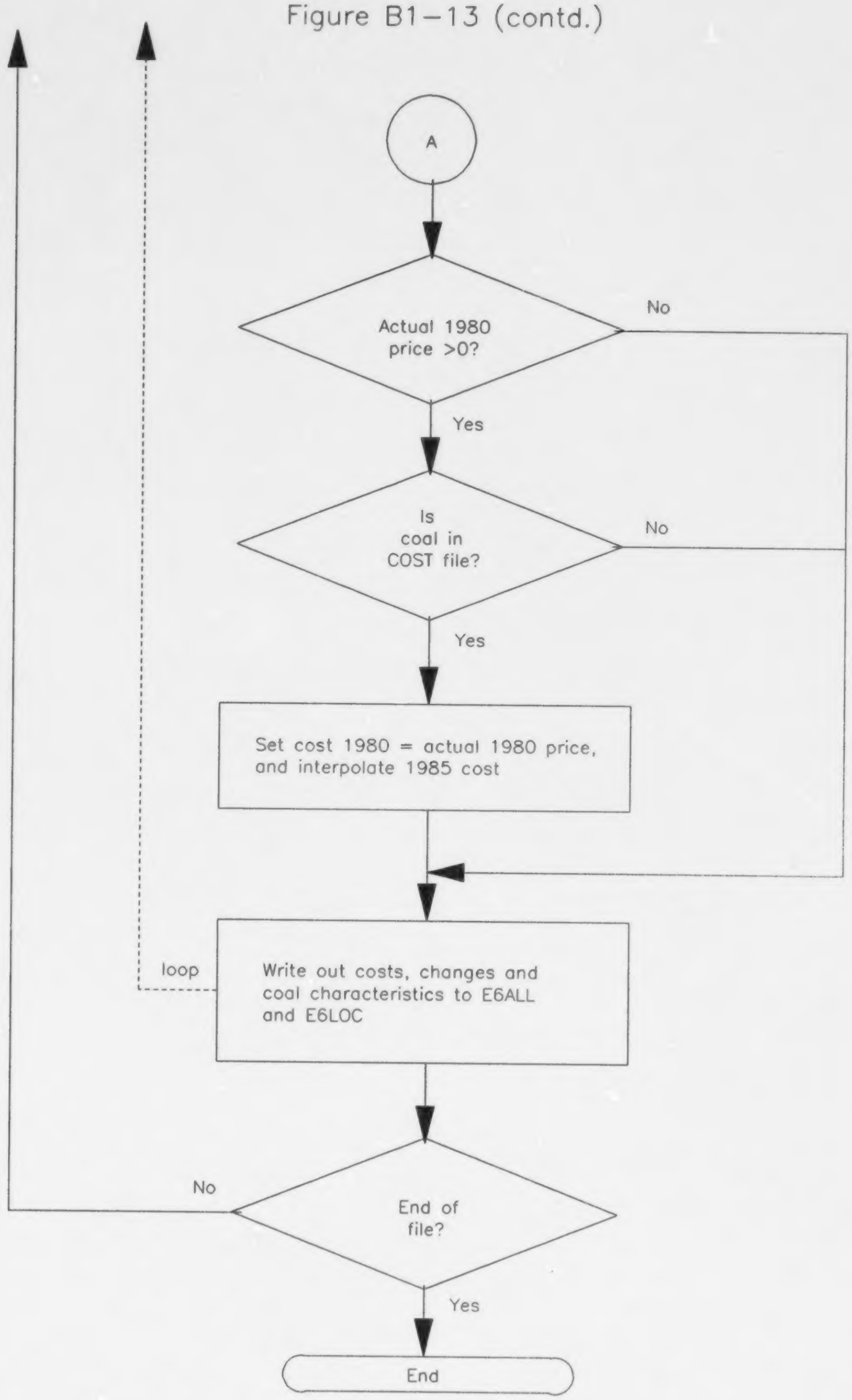

A
Actual 1980 price >0?
No
Yes
Is coal in COST file?
No
Yes
Set cost 1980 = actual 1980 price, and interpolate 1985 cost
loop
Write out costs, changes and coal characteristics to E6ALL and E6LOC
No
End of file?
Yes
End

Table B1-37

INPUT PARAMETER FORMAT

Record	Column	Format	Description
1	1-2	F2.0	Coal set indication 1=AUSM 2=EIA
2	1-2	I2	Number of simulation years
3	1-40	10F4.0	List of simulation years

Table B1-38

E6ALL AND E6LOC FORMATS

Files E6ALL (all coals available) and E6LOC (local coals given priority) have 25 header records as given below:

Record	Description	Unit/Codelist
1	Coal source flag	1=AUSM 2=EIA
2	E6 file type	0=All coal 1=Local coal
3	Number of years included	integer
4	List of years	date
5	Number of remaining parameters on E6	20
6	Inflation rate	fraction
7	Real after-tax return on equity	fraction
8	Real cost of debt	fraction
9	Real escalation of capital	fraction
10	Debt ratio	fraction
11	Real escalation of power and supplies	fraction
12	Real escalation of labor	fraction
13	Corporate tax rate	fraction
14	Real escalation of other	fraction

Table B1-38 (contd.)

Record	Description	Unit/Codelist
	costs	
15	Transportation escalator #1	fraction
16	Effective year of transportation escalator #1	date
17	Transportation escalator #2	fraction
18	Effective year of transportation escalator #2	date
19	User-specified price escalation	1 = yes 2 = no
20	Western coal escalation rate	fraction
21	Eastern coal escalation rate	fraction
22	Forced washing indicator	1 = yes 2 = no
23	Minimum weight yield	fraction
24	Threshhold SO_2 removed	fraction

Table B1-38 (contd.)

Following the header records, in ascending FIPS order, are state data consisting of a maximum of 13 records per state:

Record	Description	Unit/Codelist	Notes
1	State FIPS code	Codelist I	
2	Least-delivered cost of coals to state	cents/MMBtu	The length of this record is NYEARS • NSUL • NHHV. Prices are stored in ascending order by coal type (primary) and projection year (secondary).
3	Annual increase in least-delivered coal prices beyond the cost in the corresponding projection year.	cents/MMBtu	The length of this record is NYEARS • NSUL • NHHV. Price increments are stored in ascending order by coal type (primary) and projection year (secondary).
4	Characteristics of least-delivered coals in projection year 1.	-	The length of this record is NSUL • NHHV • 4. Data are organized in ascending order by coal type, then physical characteristics. Four items are stored for each coal type:
		Codelist J[a]	1) Supply region
		Btu/lb.	2) HHV
		Percent	3) Ash content
		Codelist K	4) Raw coal type

Note: Record 5 contains the physical characteristics of the least-delivered coals in projection year 2, record 6 for projection year 3 and so on.

[a] Codelists are specified in Appendix E of the system design document [7].

Table B1-39
FILE DEL80 FORMAT

Records 1-16 contain miscellaneous header information.

Records 17 to the end contain the following data:

Column	Format	Description	Unit/Codelist
1-2	I2	Demand region	Codelist I
6	I1	HHV category	Codelist N
12-13	I2	Sulfur category	Codelist K
17-22	F6.2	Actual price paid for coal in demand region in period 1	cents/MMBtu

---

Note: Sulfur categories are in the actual order specified by codelist K. They are not transformed by subtraction from 12 or 9.

1.6.3.1 **Subroutine ERROR.**

Called by:	MAKE6
Calls:	None
Argument:	I
Task:	Writes an error message and terminates the program whenever the user-specified inputs on unit 5 are incorrect.
Method:	ERROR stops the program whenever called. Argument I is set by MAKE 6 during the reading of input parameters. Values of I correspond to the following errors:

1. Premature end of file on parameter file.
2. Invalid value for data set type.
3. Incorrect number of scenario years.
4. Invalid starting data or incomplete list of years.

1.6.4 **Variable Definitions**

Tables B1-40 and B1-41 summarize the variables used in MAKE6.

Reproduced from best available copy.

Table B1-40
PROGRAM MAKE6: VARIABLE DESCRIPTIONS

Variable	Unit	Description
ASH	percent	Ash content of all coals demanded by region in current year
ASHL	percent	Ash content of least-cost local coals demanded by region in current year
BASH	percent	Ash content of current national coal
BASHL	percent	Ash content of current local coal
BLDC	cents/MMBtu	Least-delivered cost of current national coal
BLDCL	cents/MMBtu	Least-delivered cost of current local coal
BHHV	Btu/lb	HHV of current national coal
BHHVL	Btu/lb	HHV of current local coal
CHNGE	cents/MMBtu	Average yearly change in least-delivered cost of all national coals demanded by current region
CHNGEL	cents/MMBtu	Average yearly change in least-delivered cost of all locally produced coals demanded by current region
HHV	Btu/lb	HHV of all nationally produced coals demanded by current region
HHVL	Btu/lb	HHV of all locally produced coals demanded by current region
HYEAR	years	List of simulation years
IFIPS	Codelist I	Current demand region
ISET	0=AUSM 1=EIA	Data set indicator
ISUP	Codelist J	Supply region for each national coal demanded by current region
ISUPL	Codelist J	Supply region for each locally produced coal demanded by current region
IRAW	Codelist K	Raw coal type
IRAWL	Codelist K	Raw coal type of locally produced coal
IYEAR	Julian	List of Julian data for each year

Table B1-40 (contd.)

Variable	Unit	Description
JHHV	Codelist N	HHV category of current coal
JRAW	Codelist K	Coal type of current coal
JRAWL	Codelist K	Coal type of current locally produced coal
JSTATE	Codelist I	Current demand region
JSUP	Codelist J	Current supply region of nationally selected least-cost coal
JSUPL	Codelist J	Current supply region of locally selected least-cost coal
JTYPE	Codelist K	Sulfur category of current nationally selected coal
JTYPEL	Codelist K	Sulfur category of current locally produced coal
JYEAR	Julian	Current year
MAP	Codelist K	Array of coal categories used to reverse order of coal for categories as real from ACOAL
NCOAL		Number of coal types
NSULPH		Number of sulfur categories
NYEAR		Number of years
ORIGIN	year	First year of simulation
P1980	cents/MMBtu	Array containing actual prices paid in period 1
RECRD	cents/MMBtu	Cost of every national coal supplied to current demand region
RECRDL	cents/MMBtu	Cost of every locally produced coal supplied to current demand region

Table B1-41
PROGRAM MAKE8: VARIABLE INFORMATION

Variable	Type	Dimension	Unit
ASH	real	(40,10)	percent
ASHL	real	(40,10)	percent
BASH	real	(1)	percent
BASHL	real	(1)	percent
BLDC	real	(1)	cents/MMBtu
BLDCL	real	(1)	cents/MMBtu
BHHV	real	(1)	Btu/lb
BHHVL	real	(1)	Btu/lb
CHNGE	real	(10,40)	cents/MMBtu
CHNGEL	real	(10,40)	cents/MMBtu
HHV	real	(40,10)	Btu/lb
HHVL	real	(40,10)	Btu/lb
HYEAR	real	(1)	Date
IFIPS	integer	(1)	Codelist I
ISET	real	(1)	0=AUSM 1=EIA
ISUP	real	(40,10)	Codelist J
ISUPL	real	(40,10)	Codelist J
IRAW	real	(40,10)	Codelist R
IRAWL	real	(40,10)	Codelist R
IYEAR	real	(10)	Julian year
JHHV	integer	(1)	Codelist N
JRAW	integer	(1)	Codelist K
JRAWL	integer	(1)	Codelist K

Table B1-41 (contd.)

Variable	Type	Dimension	Unit
JSTATE	integer	(1)	Codelist I
JSUP	real	(1)	Codelist J
JSUPL	real	(1)	Codelist J
JTYPE	integer	(1)	Codelist K
JTYPEL	integer	(1)	Codelist K
JYEAR	integer	(1)	Julian year
MAP	integer	(11)	Codelist K
NCOAL	integer	(1)	Integer
NSULPI	integer	(1)	Integer
NYEAR	integer	(1)	Integer
ORIGIN	real	(1)	date
RECRD	real	(10,40)	cents/MMBtu
RECRDL	real	(10,40)	cents/MMBtu

REFERENCES

1. Energy Information Administration. **"Documentation of the Resource Allocation and Mine Costing (RAMC) Model,"** U.S. Department of Energy. DOE/NBB-0020. Washington, DC. September 1982.

2. Richard Engelbrecht-Wiggans. **"The Unconstrained Coal Washing/Transportation Algorithm."** University of Illinois at Urbana-Campaign. 1982.

3. Edward H. Pechan. **"Appendix B. The Coal Reserves Data Base." "Advanced Utility Simulation Model, Analytical Documentation, State Level Model (Version 1.0)."** U.S. Environmental Protection Agency. EPA-600/8-88-071a. January 1989.

4. John W. Green. Data tape containing 1980 mine-costing data. Colorado State University.

5. Robert Crockett. Personal communication. Energy Information Administration, U.S. Department of Energy. August 1983.

6. Energy Information Administration. **"Annual Report to Congress, 1981."** U.S. Department of Energy. DOE/EIA-0173(81). Washington, DC. 1982.

7. Caroline J. Badger and Howard Ojalvo. **"Advanced Utility Simulation Model, Documentation of System Design, State Level Model (Version 1.0)."** U.S. Environmental Protection Agency. EPA-600/8-88-071c (NTIS PB89-101208). August 1988.

8. John W. Green and Ari M. Michelson. **"Econometric Estimation of Regional Coal Price Forecasting Models for the United States."** Department of Agriculture, Economic Research Service, Colorado State University. 1983.

9. J.F. Skea and E.S. Rubin. **"Appendix C. Coal Cleaning Methodology." "Advanced Utility Simulation Model, Analytical Documentation, State Level Model (Version 1.0)."** U.S. Environmental Protection Agency. EPA-600/8-88-071a. January 1989.

B2. THE MPMS MODULE

by

R. Edahl, N. Tyle, S. Talukdar and N. Pacharis

Universities Research Group on Energy
University of Illinois at Urbana-Champaign

B2.1 Overview

The purpose of the National Model is to complement the state-level Advanced Utility Simulation Model (AUSM). In particular, the National Model calculates three critical inputs to the state-level AUSM:

- inter-state transfer of energy
- generation plant expansions aggregated to the state level
- state emission caps

It also computes the amount of each fuel used by state and period for use in the National Coal Module.

The approach used is to divide the nation into multi-state-regions so that the energy transfers across the regional boundaries will remain small over the time horizon of interest. This makes regions essentially independent from the viewpoint of generation and energy transfers. Then, a multi-period multi-state (MPMS) module is developed which can make optimal (least cost) decisions on which state to site new plants in, when to build them, what the inter-state energy transfers should be and at what levels the emission caps for each state should be set.

The multi-period multi-state (MPMS) problem is formulated as a linear programming model using aggregated, rather than the individual, plant and fuel categories. Instead of directly solving this problem as a single linear programming problem, which is potentially unmanageable, the problem is handled instead by a heuristic decomposition technique.

The method used to solve the multi-period multi-state model is to solve a sequence of backward-looking single-period multi-state problems which yield the desired information on state-aggregated additions, inter-state flows, state emissions, and fuel consumptions.

B2.2 Central Algorithms and Basic Assumptions

B2.2.1 Problem Formulation

The following general assumptions are made concerning the MPMS problem.

1. The net exports of electrical energy from the group of utilities considered to the rest of the country are known in advance,
2. Operating costs and emissions are linear functions of the operating level of generating plants and pollution control technologies,
3. Capital costs for both generating plants and pollution control technologies are linear functions of their sizes,
4. Plants are aggregated into ten categories,
5. Fuel alternatives for each plant category are aggregated into at most three categories,
6. Load demand points are aggregated into load centers,
7. Transmission losses between load centers are linear functions of power flow, and
8. Retirement years of generating units are known in advance.

B.2.2.2 Solution Method

The following assumptions about the MPMS problem have been made when developing a heuristic decomposition method:

1. Electric power demand is expected to increase over time, hence the total generation capacity requirements are expected to increase with time,

2. The time horizon of study is generally such that capacity brought online during the period of study will be operable at least until the end of the horizon,

3. The allowable emission limits are expected to decrease (or at least not increase) over time, hence CT capacity requirement are expected to increase with time, and

4. The final period of study is a steady utility model, hence it is likely that the profile of capital additions for the solution of just the last period problem would be similar (and in many instances identical) to that for last period portion of the exact solution to MPMS.

These assumptions together with other features of the MPMS problem suggest the use of a means-end algorithm using the capital variables as the control variables. This algorithm essentially tries to find the optimal capital configuration for the final period (which is a steady-state problem), and works back toward the beginning period.

B2.3 Data Handling

There are four types of data involved in using MPMS. These include national data, scenario data, intermediate data, and output data. The user must also input a trace level from the default input device (e.g the terminal) in I1 format. A level may be chosen from 0 to 3, with increasing amounts of information with the higher level. A level of 3 is recommended for the 'debugging' purposes.

B2.3.1 National Database

There are six files from the national database that MPMS uses. Theses are the two fuel datasets (coal and alternate), the two unit inventories (current and announced), the demand data, and the distance data. MPMS deals with these datasets indirectly by first running a series of auxiliary programs to generate a set of four intermediate datasets.

B2.3.2 Scenario File

The scenario file defines the region to be examined, the time periods, demand growth rate, emission limits, and other parameters to be used in solving the problem. This file is read both by the main MPMS set of programs and the auxiliary programs.

B2.3.3 Intermediate Files

The auxiliary programs read from the scenario file and the six files from the national database produce four intermediate files. These intermediate files, along with the scenario file and a new-plant characteristic file are the ones used by the main MPMS set of programs. The file names used for both the input and output files are set in subroutine OPEN of MPMS. There are six subroutines in MPMS for reading the input files, one per file.

B2.3.4 Output Files

There are six output files generated by the MPMS package: a report file to be used by AUSM, a verbose report file, a trace file, and a set of messages generated by the XMP [1] linear programming package. The other two files are concerned with predicted construction of new generating capacity. The first is a table of predicted scheduled new capacity (by year, state, and plant category), and the second is a modified announced unit inventory file.

B2.4 Program and Subroutine Summaries

The following sections outline the four preparatory programs and the MPMS program.

B2.4.1 Preparatory Programs

Fuel Aggregation

CLRD

Called by: MPMSAI

Calls: INTERP

Arguments: CHAR, FCST, FNAM, IST, IYRA, NIYRA, NPER, NSTATE, NYR

Tasks: CLRD reads in the coal data and aggregates it over the higher-heating values. It prints out the fuel characteristics for the various states and time periods.

Method: Linear interpolation is performed on the fuel characteristics over time to yield values for the intermediate periods.

INTERP

Called by: CLRD

Calls: None

Arguments: IYR, NYR, NYRT, II, ALPH

Tasks: INTERP finds the coefficients for a linear interpolation.

MPMSA1

Called by: None

Calls: CLRD

Tasks: The purpose of the Fuel Program is to generate an information file of the fuels available to the
plants in the region. This program reads in the alternate fuel information and calls CLRD to read
in the coal information and write the regional fuel file.

Method: Data from the two fuel files and the scenario file are read in. Linear interpolation is performed on the fuel characteristics over time to yield values for the intermediate periods.

Unit Aggregation

ADDANN

Called by: AGGREG
Calls: TECHCK
Arguments: ISTONE, ISTTWO, I, ICOUNT
Tasks: To read in data from the announced unit inventory file.

AGGREG

Called by: MPMSA2
Calls: SCHANG, ADDANN, PRHEAD
Arguments: REGNAM, IRUN, NSTAT, ISTAT, IBYEAR, NPER, LENPER, NCOAL, ICODE
Tasks: AGGREG is the main subroutine. It controls the input, aggregation, and output.

MPMSA2

Called by: None
Calls: AGGREG
Tasks: The purpose of MPMSA2, the regional aggregation program, is to pull out from the unit inventory files the information describing plants from a collection of state which have been grouped into a Region. The information aggregated, for each state by fuel type and, for coal plants, size and age to yield ten categories. Appropriate information characterizing each category is computed for output for each period.
Method: Data from the two inventory files and the scenario file are read in. the units in each state and/or each time period are aggregated into ten predefined categories.

PRHEAD

Called by: AGGREG
Calls: None
Arguments: REGNAM, NSTAT, ISTAT, STNAME, IBYEAR, IESTUD, NPER
Tasks: Prints the header for the aggregated unit file.

TECHCK

Called by: ADDANN

Calls: None

Arguments: ITECH, IFUEl

Tasks: Determine the fuel type for units in the announced unit inventory file

Method: A data statement determines the mapping

XCHANGE

Called by: AGGREG

Calls: None

Arguments: K, J

Tasks: To swap records for k and j

Demand Program

INTERP

Called by: MPMSA3

Calls: None

Arguments: IRY, NYR, NYRT, II, ALPH

Tasks: INTERP finds the coefficients for a linear interpolation

MPMSA3

Called by: None

Calls: INTERP

Tasks: The purpose of MPMSA3, the demand program, is to generate load curves for the various states in the regions and the varius time periods.

Method: Data from the demand file and the scenario file are read in. The demand growth rate from the scenario file is used, in conjunction with the initial sales figure, to project state demand for the desired future periods. The load factors for the samples years from the demand file are interpolated to yield the peak estimates for the various years.

MPMSA4

Called by: None

Calls: None

Tasks: The purpose of the Transmission program is to generate a table showng the efficiency rate for transferring from one state to another in the region and the line rental costs involved.

Method: Data from the distance file and the scenario file are read in. A simple linear relationship between line length and percent power loss is assumed to yield the line efficiencies.

B2.4.2 MPMS Programs

COLPCK

Called by: DISAG

Calls: None

Arguments: COLA, COLI, COLLEN, INROW

Tasks: To pack the columns sent to XMP

DEMRD

Called by: Main Program

Calls: None

Arguments: LOAD, NII, NPER, NREG, SCALE

Tasks: To read in the demand data

DISAG

Called by: Main Program

Calls: XMPAS, COLPCK, XADDAJ, XADDUB, MFUEL, SCRBCP, SCRB, XCLACK, XPRIML, XGETUB, XGETAJ, XDOT, VALUE

Arguments: ALOS, AVAIL, AVG, CAPCOS, CF, CT0, DSCAP, DSCAPT, DSVAR, DVS, DVT, EMAX, FUEL, HTR, HHV, HOURS, ICAP, IPLNT, ISCRUB, LOAD NFL1, NFL2, NEMM, NH, NPLNT, NTAG, NREG, OM, PO, PBND, PSO2, SOLU, TH, Z, LENMY, MEMORY

Tasks: To set up a single-period linear programming program and call the XMP library subroutines to solve.

Method: Sets up columns for problems as if all plant categories were alike (i.e. used scrubbers, etc), then packs the columns, eliminating the superfluous rows.

DSPRNT

Called by:	Main Program
Calls:	MFUEL, SCRB
Arguments:	ALOS, AVAIL, AVG, CF, CT0, DVT, FLOW FUEL, HTR, HHV, HOURS, ITRACE, NFL1, NFL2, NH, NPLNT, NREG, NT, NTAG, PO, POL, PSO2, SOLU, TCST, TH, TRANS
Tasks:	To write a trace file and to retrieve the desired information from the solution of DSPRNT

FUELRD

Called by:	Main Program
Calls:	None
Arguments:	NFLTL, FUEL, HHV, NPER, PSO2
Tasks:	To read in the fuel data.

INVRD

Called by:	Main Program
Calls:	None
Arguments:	ADDMAX, AVAIL, AVG, AVGN, AVN, CAPBND, CAPCOS, CF, CFN, CT0, CSTN, CTMAX, HTR, HTRN, ICAP, ISCRUB, NFL1, NFL2, NFLTL, NPER, NPLNT, NREG, OM, OMN, PO, SCALE
Tasks:	To read in and scale the aggregated plant data.

MFUEL

Called by:	DISAG, DSPRNT
Calls:	None
Arguments:	CST, EMM, FUEL, HTR, HHV, NFL1, NFL2, PSO2
Tasks:	Compute the cost and emission rates (per MWHr) for the fuels used by a single plant category in a single state.

MAIN PROGRAM

Called by:	None
Calls:	OPEN, SCNRD, NPLRD, DEMRD, TRNSRD, FUELRD, INVRD, UPDATE, DISAG, DSPRNT, REGRPT
Tasks:	The controlling program for MPMS

NPLRD

Called by: Main Program
Calls: None
Arguments: AVGN, AVN, CFN, CSTN, NTRN, OMN
Tasks: To read in the new plant characteristics.

OPEN

Called by: Main Proglram
Calls: None
Arguments: None
Tasks: Open files for input and output.

REGRPT

Called by: Main Program
Calls: None
Arguments: AVAIL, CF, DIS, DISVAR, DV, EMAX, FLOW, HOURS, ICAP, ISTAT, IYR, LOAD, NAME, NH, NPER, NPLNT, NREG, NYR, POL, PSO2, RISE, STATE, TCST, TH, TITLE, TRANS
Tasks: To write the two main reports.

SCNRD

Called by: Main Program
Calls: None
Arguments: DIS, DISCAP, DISVAR, EMAX, HOURS, ICAP, ISTAT, IYR, NAME, NEMM, NH, NPER, NPLNT, NREG, NYR, RISE, STATE, TH, TITLE
Tasks: To read in the sceario parameters and to compute the discount factors to be used for the periods.

SCRB

Called by: DISAG, DSPRNT
Calls: None
Arguments: AVG, CST, EMM, FUEL, HTR, HHV, NFL1, NFL2, POW, PSO2
Tasks: Compute the cost and emission rates (per MWHr) for the scrubbed fuels used by a single plant category in a single state.
Method: Uses formula and coefficients from [2] for the cost and power loss figures.

SCRBCP

Called by: DISAG
Calls: None
Arguments: AVG, CAP, HTR, HHV, NFL1, NFL2, PSO2
Tasks: To compute the capital costs of retrofitting scrubbing capacity
Method: Uses formulae and coefficients from [2] for the cost

TRNSRD

Called by: Main Program
Calls: None
Arguments: ALOS, NREG
Tasks: To read in the transmission data.

UPDATE

Called by: Main Program
Calls: None
Arguments: CAPBND, CT0, CTMAX, CDT0, DISCAP, DSCAP, DSCAPT, FIRST, ICAP, ISCRUB, NPER, NPLNT, NREG, NT, NTAG, PBND, SOLU
Tasks: To compute the bounds for the captial variables and the coefficients used to multiply the costs (both variable and capital) to be used in the next call to DSPRNT.

VALUE

Called by: DISAG
Calls: XGETUB
Arguments: BASIS, BNDTYP, BOUND, IOERR, J, LENMA, LENMY, M, MAPA,M MEMORY, NTYPE2, STATUS, XBZERO
Tasks: To retrieve the value of the j^{th} solution variable from XMP.
Method: This function is a modification of the XMP subroutine XPRINT.

B2.5 Variable Definitions

Below is a list of variables used in the MPMS module except for the variables used by XMP which are described in detail in the AUSM program document. Several of the arrays below are packed.

ADDMAX(NT,IK)

is the maximum capacity addition allowed in period NT to the IK^{th} plant category that can be added to real (itag(1,i)ALOS(1,I,J)

efficiency of the line connecting state I to state J (fraction)

ALOS(2,I,J)

cost of line rental ($/MWHr)

AVAIL(NP,NS,NT)

availability of plant category NP in state NS in time period NT (fraction)

AVG(NP,NS,NT)

average size of plant in plant category NP in state NS in time period NT (MW)

AVN(NP)

size of new plant category NP

CAPBND(1,NT,IK)

is the lower bound ong eneration expansion in period NT for new plant category IK

CAPBND(2,NT,IK)

is the upper bound on generation expansion in period NT for new plant category IK

CAPCOS(IK)

is the capital cost for additon to the IK^{th} plant category that can be added to real (itag(1,i)

CF(NP,NS,NT)

is the capacity factor for plant category NP in site NS in period NT (fraction)

CFN(NP)

is the capacity factor for new plant category NP (fraction)

CSTN(NP)

is the cost for capacity for new plant category NP ($/MW)

CTO(NT,IK)

is the scheduled capacity in period NT for the IK^{th} pollution control device (MW) (itag(2,i)nemch)

CTMAX(NT,IK)

is the maximum allowable addition in period NT for the IK^{th} pollution control device (MW)(itag(2,i), nemch)

DISCAP(NT)

discount factor used for capital costs in period NT

DISVAR(NT)

discount factor used for variable costs in period NT

DCT0(IK)

a temporary array, is the scheduled capacity in period NT for the IKth pollution control device (MW) (itag(2,i),nemch)

EMAX(NT)

is the standard in period NT for SO2 (Tons/year)

FUEL(N,NT)

is the cost in period NT for fuel N (cents/MMBTU)

HHV(J,NT)

is the higher heating value in period NT for fuel J (MMBTU/Lb)

HOURS(NHH,NT)

is the number of hours in the NHHth segment of the LDC in period NT (real)

HTR(I,NS,NT)

is the heat rate of plant category I, state NS, period NT (MMBTU/MWHr)

HTRN(IK)

is the heat rate of new plant category I (MMBU/MWHr)

ICAP(I,NS)

is a pointer to the capcos and addmax arrays. If no generation additions are allowed for category I in state NS, ICSP is 0.

INROW(L)

is a mapping for the rows in the apcking procedure DISAG. INROW=0 means the row does not exist (i.e. no scrubber constraints for nucelar power plants), and

IPLNT(I,NS)

is an array used in DSPRNT. Is 0 if plant I in state NS does not have any scheduled or potential capacity in the current period.

ISCRUB(I,NS)

is a pointer to the ctmax array. If no scrubber additions are allowed for category I in state NS, ICAP is 0

LOAD(NHH,NS,NT)

is the demand for the NHHth segment of the LDC in state NS in period NT (MW)

MEMORY

is the main working array for XMP

NFL1(1,I,NS)

is the number of fuel options for plant category I in state NS (integer)

NFL1(2,I,NS)

points to the first occurrence of a fuel for plant category I in state NS in the NFL2 list

NFL2(J)

is a mapping of fuels (points to the FUEL, HHV, and PSO2 arrays)

NH

is the number of segments of the LDC (integer)

NPER

is the number of periods (integer)

NPLNT

is the number of plant categories (integer)

Ntag(1I,NS)

is 0 if no additions are allowed for category i, otherwise SOLU(j) for j from Ntag(1,I,NS) to Ntag(1,I,NS)+nper-1 are the capacity additions to category i

Ntag(2,I,NS)

points to the differential operating level of the first fuel in plant category I for the first period. Differential operating levels for I's fuel j in period n for the K^{th} segment of the LDC is then given by SOLU(ntag(2,INS)+k-1+(nt-1)*nh+(j-1)*nh*nper)

Ntag(3,I,NS)

points to the flow variables

Ntag(4,I,NS)

is 0 if plant category I does not have pllution control addition as a variable, otherwise SOLU(Ntag(4,I,NS)+nt-1) is the scrubber addition to category i in period nt.

Ntag(5,I,NS)

is 0 if plant cateogry I does not have pollution control operation as a variable, otherwise SOLU(ntag(5,I,NS)+nt-1+(j-1)*nper) is the pollution control operation for I's j^{th} fuel in period nt.

OM(I,NS,NT)

is the O&M cost for plant category I state NS, period NT ($/MWHr)

OMN(IK)

is the O&M cost for new plant category IK ($/MWHr)

P0(I,NS,NT)

is the scheduled capacity of plant category I, state NS, period NT (MW)

PSO2(J,NT)

is the sulfur content in period NT for fuel J (fraction)

SOLU(k)

output vecotr (real) (see below)

REFERENCES

1. R.E. Marsten. **"The Design of the XMP Linear Programming Library"**. ACM Transactions on Mathematical Software. Vol. 7, No. 4, pp. 481-497. December 1981.

2. E.S. Rubin. **"International Pollution Control Costs of Coal-Fired Power Plants"**. Environmental Science and Technology. Vol. 17, No. 8, pp. 366a-377a. 1983.

C3. THE CONTROL PROGRAM

by
Caroline J. Badger and William H. May

Universities Research Group on Energy
University of Illinois at Urbana-Champaign

3.1 Overview

The state-level Advanced Utility Simulation Model (AUSM) is a FORTRAN-based program with seven major components. The monitoring or control program and the six analytical modules are described elsewhere in this report.

The control program is described as the main program unit of the AUSM and the FORTRAN procedures (subroutines, function subprograms and a block data subprogram) are provided to perform the following functions: (1) invoking the 6 analytical modules, (2) provide data-handling, (3) implementing scenario dependent parameters, (4) provide standard error-handling and (5) carry out special data manipulations common to all modules. These 5 tasks are discussed in detail in the following sections.

3.2 Control Program Tasks

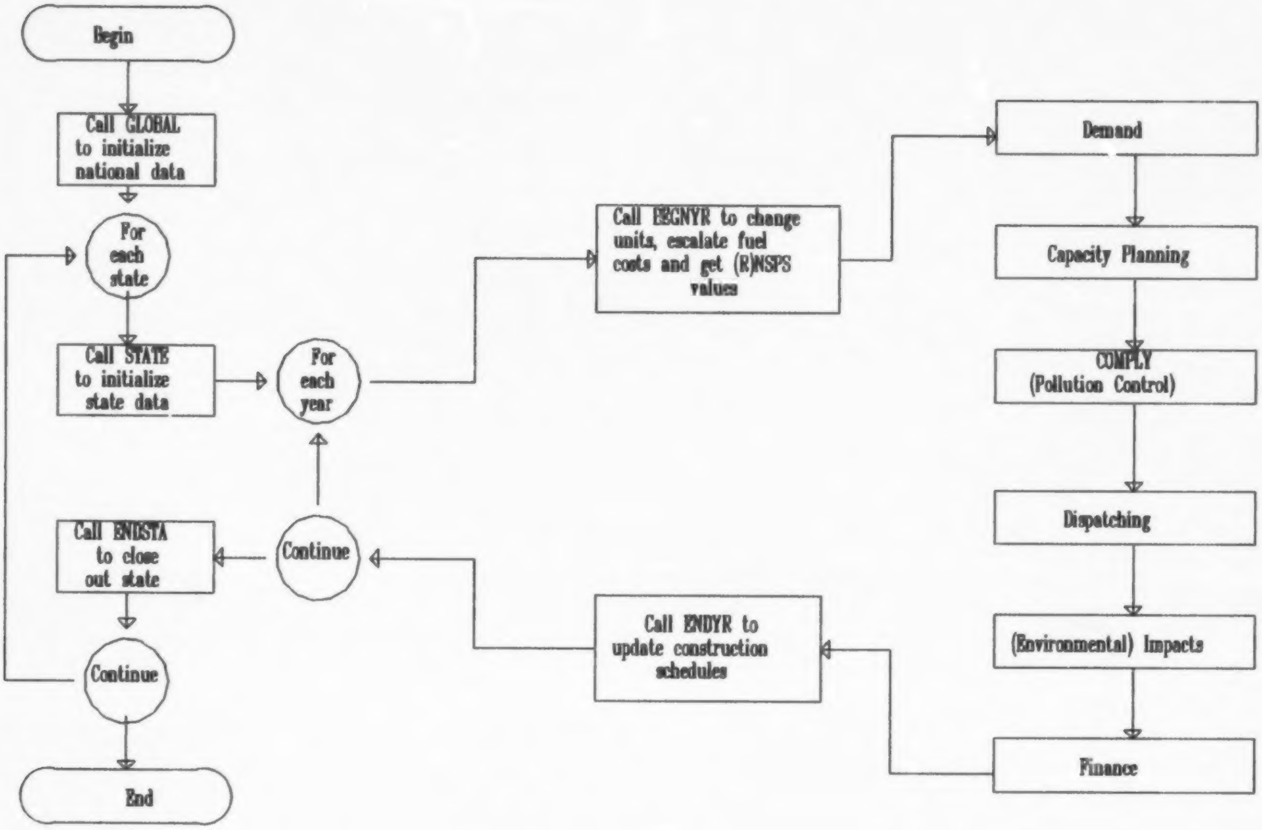
3.2.1 Invocation of Analytical Modules

The state-level AUSM is an annually recursive simulation model that may be executed for any number of states in sequence. Figure C3.1 depicts the annual flow of control through the major components of the model.

Note that five major subprograms are associated specifically with the control program: GLOBAL, which initializes national (as opposed to state-specific) exogenous data; STATE, which initializes state-specific exogenous data; BEGNYR and ENDYR, which perform certain annual "housekeeping" tasks at the beginning and end of each year; and ENDSTA, which closes out a state. In turn, the five subroutines call other control procedures. More detail is provided in Sections C3.3 and C3.4.

Figure C3-1

AUSM LOGIC FLOW


Begin
Call GLOBAL to initialize national data
For each state
Call STATE to initialize state data
For each year
Call BEGNYR to change units, escalate fuel costs and get (R)NSPS values
Demand
Capacity Planning
COMPLY (Pollution Control)
Dispatching
(Environmental) Impacts
Finance
Call ENDYR to update construction schedules
Continue
Call ENDSTA to close out state
Continue
End

3.2.2 Provision of Data-Handling Routines

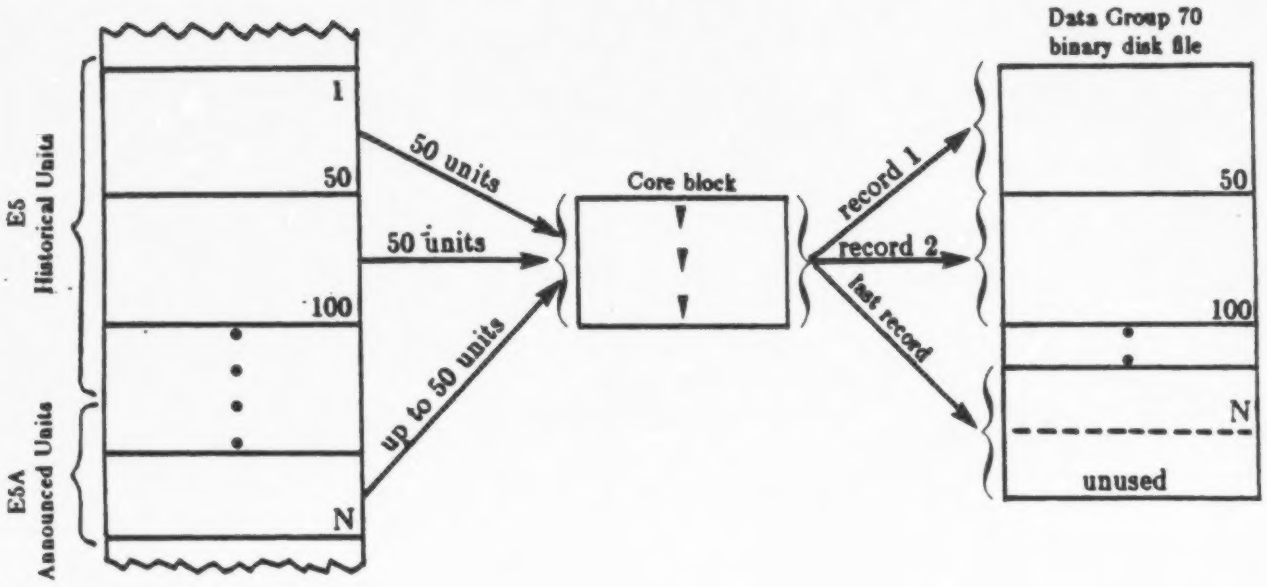
3.2.2.1 The Generator Inventory. An exogenous generator inventory (files E5 and E5A) is prepared from the unit inventory tape compiled by E.H. Pechan & Associates (for details see Reference 1). The E5 and E5A files contain data on generating units in the 48 continental states, Alaska, and the District of Columbia. The formal layout of E5 and E5A, as well as the other data sets, is shown in the AUSM system design document [2].

When a state is initialized for a simulation run by AUSM, the E5 files are positioned to the first unit in the state. Units (all historic active units from E5 followed by announced units from E5A) are transferred to a block of core in uniform groups. The size of the group of units is set internally (for illustration here we use a group blocking factor of 50 units). The entire core block is written as a *single* binary record to a binary sequential file. When all the units for the state have been transferred to the binary file in records of 50 units each, the first record (units 1-50) is read back to the core block. This file is the initial data group 70 for the state. The core block always holds units from a single record of the data group 70 file; up to 50 units can be held. Figure C3-2 illustrates the construction of the initial binary file for data group 70.

AUSM modules locate units through standard calls to [S]GET/PUT. The unit may reside in core, i.e., be one of the units in the core block, in which case the access can be performed directly to or from core. But if the unit is in one of the binary file records, that record must be brought to core and the specific unit data made available. As units are accessed, a second binary sequential file is kept up to date. If any unit data are changed by SPUT, the second disk file contains the updated unit information and will be exchanged with the current disk file for future access.

Suppose, for example, that the first record from the source file is in core and that a call is made to SPUT to make changes to unit 183. Records are copied from the source file to the destination file until the record containing the requested unit is in core (the fourth record). The changes are made to unit 183 in core. A switch is kept to indicate changes, and when a change is made the switch is turned on. The fourth record is kept in core until a request for a unit in a different record is made. The source and destination files are maintained in parallel until the end of the files are reached. If a change has been made,

Figure C3-2
CONSTRUCTION OF DATA GROUP 70 BINARY FILE FROM E5 FILE



the second file becomes the source file and the first file becomes a new destination file. If a nonsequential call is made for access to a unit already transferred to the destination file (for example, unit 47) a check of the change switch is made. If no changes were made, the current source file is simply rewound and the requested unit brought to core. However, if a change has been made, the destination file must be completely written to the end of data group 70 before being rewound and used as the new source file.

New units are added to the end of data group 70. If the new unit being added is the first unit of a new record, the record is formed in the core block and written to the destination file. Retired unit data remain in data group 70 for the entire simulation period.

Although this method allows the modules random access to the units, it is obvious that sequential access is most efficient. Also it should be noted that if the entire data group 70 is less than the core block size, no peripheral I/O is involved. A blocking factor of about 150 would probably use two disk records for 90 percent of the state inventories. However, the blocking factor must be chosen with respect to the amount of core space available at a user's installation.

3.2.2.2 **Construction Schedules**. The four unit construction schedules—data groups 23 (new unit construction), 32 (SO_2 retrofit construction), 33 (NO_x retrofit construction), and 34 (TSP retrofit construction)—have the same data structure and access techniques. Data group 23 differs from the others only in the number of items stored for each unit.

These data groups are structured as indexed sequential access data sets with primary storage in core and overflow units written as direct access records to a disk file. A fixed total number of units is allowed. The data sets are updated annually in a simulation and overflow records are moved to primary storage in core whenever primary storage space becomes available. The data sets are never resequenced.

Two index arrays are used. The first is an index to available free space (either in core or on disk). The second keeps the sequential order of a construction schedule and is used to point to the location of the data for a unit. On initialization of a state, these arrays are cleared to "no units" and "all space free." As units are added to a schedule, the data are placed sequentially in core. When the primary core storage is filled, units are written to disk. At the end of a simulation year, units that have come on-line are deleted from the schedule. This is accomplished by clearing the appropriate index in the free space vector and updating the sequential order location index.

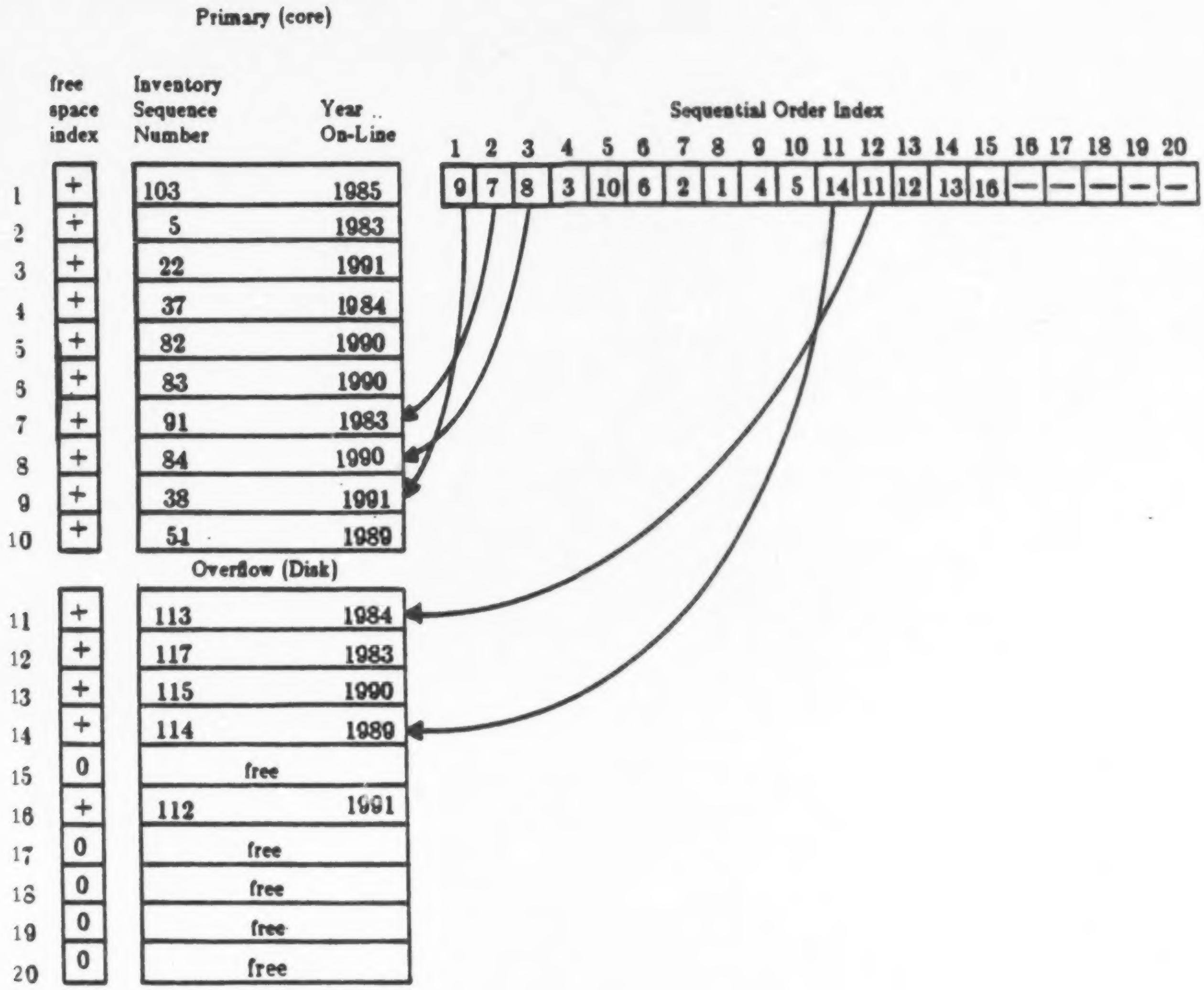
Figure C3-3 illustrates the relationship between the two indices and the primary and overflow storage areas. In this hypothetical example the primary storage holds ten records and the overflow holds an additional ten. The simulation is for the year 1983. The figure shows the schedule at the beginning of 1983 with 15 units. The unit inventory sequence number and year on-line are the only items represented from the data set. The free space index on the left has a value of 0 if a location is free. Locations 15 and 17-20, all on disk, are free. The sequential order index on the right points to the location of unit data. The data of the first unit in the schedule are located in the ninth location in core. Data for the second unit are in location 7, and so on, to sequential number 11, which is in the fourth location on disk. Sequential number 12 is in the first disk location.

Figure C3-4 illustrates the schedule at the end of 1983. Three units have been deleted: inventory sequence numbers 5, 91, and 117. They were in the second, seventh, and twelfth locations in the construction data group, respectively. The deletion procedure scans the sequential order index in order, looking at the year on-line in the location indicated. If the year on-line is current, the space is made free and the sequential order index is adjusted. If the year is not current, no deletion is performed and the unit remains in the construction schedule. If the data are stored on the disk (an overflow record), free space in core is sought, and if found, the data are moved to the free space. In Figures C3-3 and C3-4, for example, the eleventh unit in the schedule (inventory sequence number 114 in Figure C3-3) becomes the ninth sequential unit (Figure C3-4), and the data have been moved from the fourth disk location into the second location of core. The thirteenth sequential unit in Figure C3-3 has been deleted, and its disk space at disk location 2 is now free.

In the next year, new units added to the schedule would use disk locations 1, 2, 4, 5, 7, and so on. An attempt to add a unit greater than the maximum of a schedule (20 in this example) would initiate an abort procedure.

Figure C3-3

HYPOTHETICAL CONSTRUCTION SCHEDULE AT THE BEGINNING OF 1983



Primary (core)

	free space index	Inventory Sequence Number	Year On-Line
1	+	103	1985
2	+	5	1983
3	+	22	1991
4	+	37	1984
5	+	82	1990
6	+	83	1990
7	+	91	1983
8	+	84	1990
9	+	38	1991
10	+	51	1989

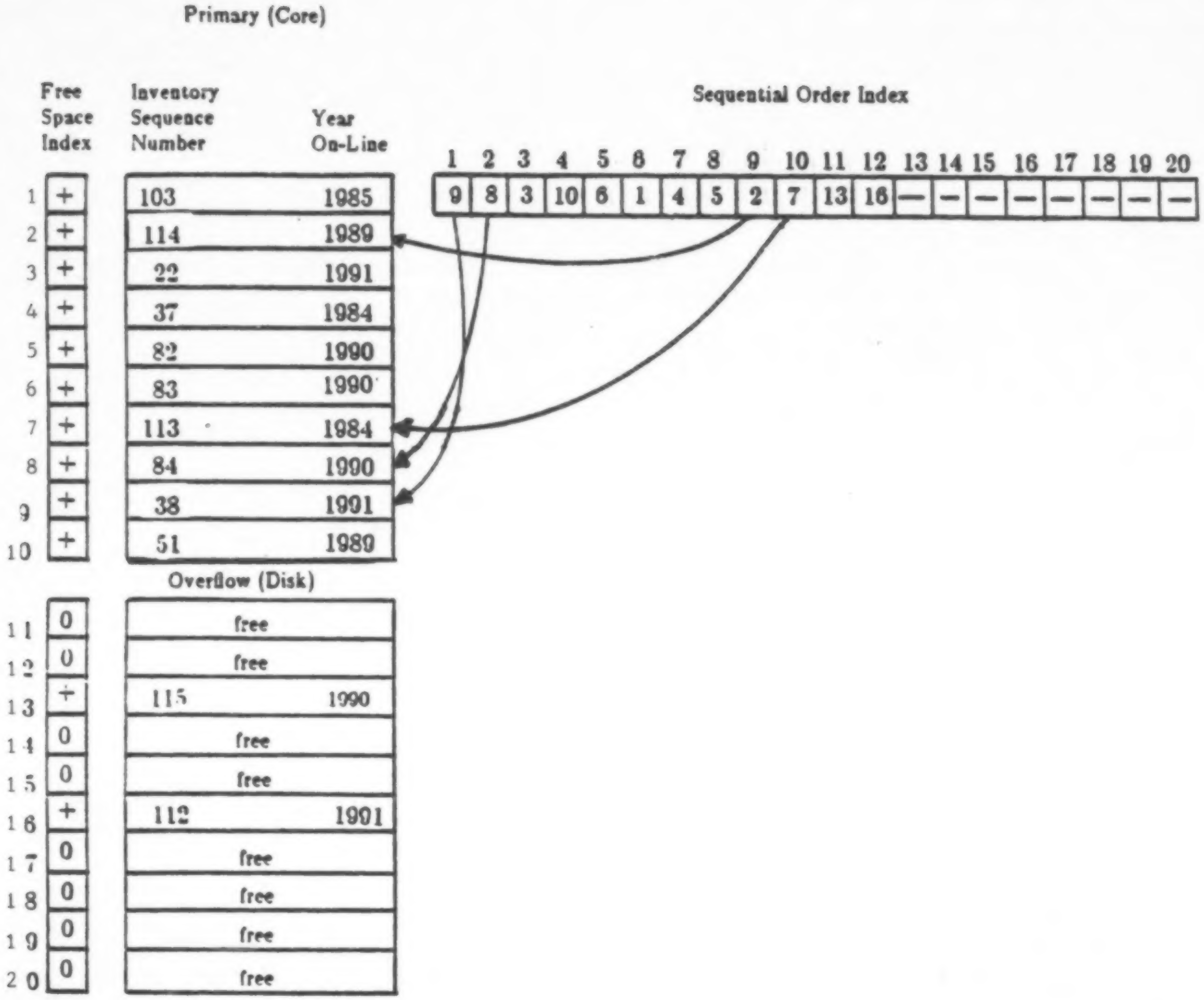
Overflow (Disk)

	free space index	Inventory Sequence Number	Year On-Line
11	+	113	1984
12	+	117	1983
13	+	115	1990
14	+	114	1989
15	0	free	
16	+	112	1991
17	0	free	
18	0	free	
19	0	free	
20	0	free	

Sequential Order Index

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
9	7	8	3	10	6	2	1	4	5	14	11	12	13	16	—	—	—	—	—

Figure C3-4
HYPOTHETICAL CONSTRUCTION SCHEDULE AT THE END OF 1983



Primary (Core)

	Free Space Index	Inventory Sequence Number	Year On-Line
1	+	103	1985
2	+	114	1989
3	+	22	1991
4	+	37	1984
5	+	82	1990
6	+	83	1990
7	+	113	1984
8	+	84	1990
9	+	38	1991
10	+	51	1989

Overflow (Disk)

	Free Space Index	Inventory Sequence Number	Year On-Line
11	0	free	
12	0	free	
13	+	115	1990
14	0	free	
15	0	free	
16	+	112	1991
17	0	free	
18	0	free	
19	0	free	
20	0	free	

Sequential Order Index

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
9	8	3	10	6	1	4	5	2	7	13	16	—	—	—	—	—	—	—	—

Choosing an appropriate size for the primary storage area is an optimizing factor. Since FORTRAN direct access I/O is relatively inefficient, this factor should be set after considering the core space available at a user's installation.

3.2.2.3 **Other Data Groups.** The data handling for all other data groups is far less complex than that required for the unit inventory and the four construction schedules. In general, the control program allocates core storage space for each data group (usually an array named DGxx) and simply transfers data to and from this core storage area upon request, with exogenous input files being read in subroutines GLOBAL, STATE, and GET. See Table C3-1 for the storage location of all data groups but the unit inventory and the construction schedules. In a few instances, the control program must provide more than simple data transfers.

Much of the exogenous demand data and some of the fuel price data exist as projected data points rather than as full time series. A subroutine named PROJ1 is called by the control program to interpolate between projected values. Table C3-2 lists the arrays used to store the projection years and values for each affected data group. All but two arrays are located in named common block /DMDINP/; PRICE and NFYRS are located in /GENERL/.

The control program also applies user-specified scaling factors to certain data passed in data groups 13 and 74. In data group 13, income, populations, earnings, and employment figures are scaled according to scenario parameters 81, 82, 83, and 84, which represent percentage growth rate over the base for each indicator. To implement this option, the value passed in data group 13 is determined by

$$Y_t = Y'_t * \exp(a * (t\text{-}1980)) \qquad \text{[Eq 1]}$$

where Y'_t is the interpolated value of the variable, t is the current year, and a is the associated growth rate divided by 100.

The interpolated prices for oils, natural gas, and nuclear fuel are similarly scaled according to scenario parameters 91, 92, and 93, respectively, percentage growth rates over the base for each fuel type. In this case, the price of the fuel passed in data group 74 is determined by

$$P_t = P'_t * \exp\,(b * (t\text{-}1980) \qquad \text{[Eq 2]}$$

Table C3-1

STORAGE LOCATIONS OF DATA GROUPS

Data Group	Storage Arrays	Common blocks
10	DG10(295)	/DMDCOM/
11	DG11(5)	/DMDCOM/
12	None, read directly	
13	DG13(5)	/DMDCOM/
14	DG14(34)	/DMDCOM/
15	DG15(8)	/DMDCOM/
16	DG16(50)	/DMDCOM/
17	DG17(5,4) and	/DMDCOM/
	TRNPOW(30,2)	/DMDINP/
18	DG18(5)	/DMDCOM/
19	DG19(4)	/DMDCOM/
20	None, read directly	
21	DG21(6)	/PLNCOM/
22	DG22(3)	/PLNCOM/
24	DG24(135)	/PLNCOM/
25	DG25(26)	/PLNCOM/
26	DG26(23)	/PLNCOM/
30	None, read directly	
31	DG31(15), RNSPS(23),	/CTCOM/
42	DG42	/DSPCOM/
60	DG60(121)	/FINCOM/
61	DG61(14)	/FINCOM/
62	DG62(8)	/FINCOM/
63	DG63(10)	/FINCOM/
64	DG64(450)	/FINCOM/
65	DG65(16)	/FINCOM/
71	TOTYR,CPRICE(40,10)	/COAL/
72	CCHAR(40,4)	/COAL/
73	DG73(3,7)	/GENERL/
74	DG74(6)	/GENERL/
75	TOTYR, CYEARS(10)	/COAL/

Table C3-2
PROJECTION YEARS, PROJECTION VALUES, AND DATA GROUPS

Projection Years	Projection (Value)	Data Group
IGNAT(5)	VGNAT(5,5)	11
IGBEA(5)	VGBEA(5,5)	13
IGNERC(5)	VGNERC(5,5)	13
YRS17(5)	DG17(5,4)	17
IGA1(5)	VGA1(5,5)	currently unused
IGA2(5)	VGA2(5,5)	currently unused
NFYRS(10,7)	PRICE(10,7)	74

where P^f_t is the interpolated fuel price, t is the current year, and b is the fuel growth rate divided by 100.

Data group 31, (R)NSPS, is also handled as a special case. A detailed discussion of the implementation for data group 31 appears in Section 3.2.3.

Data group 72 (coal characteristics) has data for only certain projection years in a simulation. The number of years and actual dates are in data group 75. For access to data group 72 the sequence number of the projection year is required. This sequence number corresponds to the actual date year held in data group 75.

Only one year of coal characteristics is kept in core, in array CCHAR(40,4). When data from data group 72 are requested, the control program checks the year for data currently in core and simply passes the appropriate values. If the request is for data from another year, the exogenous file E6 is positioned to the correct record and the CCHAR array is read before the request is satisfied.

3.2.3 Implementation of Scenario-Dependent Parameters

Certain variables used in the model may be specified by the user. There are currently 106 global variables and 87 state-level variables or vectors that are user specified. some of these user-specified values are stored in vector PARAM in common block /SCENAR/. Two hundred storage locations are allocated to allow for future expansion. The first 106 locations in PARAM contain the global parameters. Locations 107 through 125 hold the first 19 state-level variables. Access to these parameters is attained by invoking function GETSCN using the arguments shown in Tables C3-3 and C3-4.

The next 46 state-level variables are handled slightly differently. These variables are the 23 building fractions representing the technology mix for new unit construction, the 23 user-specified overrides to current (R)NSPS emission standards, and the years in which the user wishes the new standards to come into effect. The technology mix is read directly to, and is passed through, data group 26. To simplify access by individual modules, (R)NSPS standards are passed via data group 31. Thus, in any given year, data group 31 contains the standards to be applied in that year.

Default emission standards for new units are stored in vector DG31IN, dimensioned as 15. User-specific overrides are read in subroutine STATE and stored in a 23-element vector named RNSPS. A 15-element vector named DG31 holds the current standards accessed via calls to data group 31. When a state is first accessed, the global default standards from DG31IN are transferred to this array. Each year, subroutine BEGNYR checks array RNSPS to see if any user-specified standards are to be applied. If so, pertinent information is transferred from RNSPS to DG31. DG31 and RNSPS are stored in common block /CTCOM/; DG31IN is a local array in subroutine STATE.

Following the building unit fractions are six vectors representing data group 17, expected growth rates for demand of electricity, gas, oil, and coal. The first vector, the end years for the five exogenous demand time periods, is read to YRS17. The next four vectors are read directly to data group 17.

The quantities and costs of net power transfers are the next 12 vectors. The first six, quantities, are read directly to TRNPOW(i,1) and the second six, costs, are read to TRNPOW(i,2).

The last four variables, actual levels of demand in a user-specified recalibration year, are read directly to data group 19.

Table C3-3

GLOBAL SCENARIO PARAMETERS

Parameter	GETSCN Index	Default	Note
General			
Number of states to include	1	1	
FIPS codes for states in simulation	2-51		
First year of simulation	52	1980	1980 is only valid value in current model.
Number of years in simulation	53	20	Maximum is 30 years.
Economic			
Inflation rate	54	0.06	
Interest, new debt	55	0.13	Nominal
Desired preferred equity return	56	0.13	Nominal
Desired common equity return	57	0.15	Nominal
Capacity Planning			
Construction cost escalation rate: nuclear	61	0.0	
Construction cost escalation rate: non-nuclear	62	0.0	
Construction deferral fraction	63	0.5	Fraction of total construction costs that must be incurred before a scheduled unit is exempt from deferral.
Year before which baseload plants may not be deferred	64	1980	
Year before which no unit may be scheduled or advanced	65	1980	

Table C3-3 (contd.)

Parameter	GETSCN Index	Default	Note	
Operation of Model				
MPMS switch	66	0	0 -	normal run,
			1 -	Data are provided from an MPMS run.
Dispatching method	67	1	0 -	merit order
			1 -	least-cost linear programming solution,
			2 -	least SO_2 emission linear programming solution
			3 -	least NO_x emission linear programming solution
			4 -	least TSP emission linear programming solution.
Coal data source	68	1	1 -	AUSM, 2 - EIA
Local coal switch	69	0	0 -	select least-cost coal,
			1 -	select least-cost local (i.e., in-state) coal if one is available.
Exogenous capacity planning switch	70	0	0 -	supervises plant construction in "normal" mode, advancing and deferring scheduled plants and adding new plants as required,
			1 -	uses construction schedule as announced in 1980; no advancements or deferrals are permitted and no new plants are scheduled.
Pollution Control Options				
SO_2 compliance option in time period 1	71	0		During the first time period coal-fired units may be brought into compliance by 0 - scrubbing or coal switching, 1 - scrubbing only, or 2 - coal switching only. Before the first time period both scrubbing and switching are permitted.

Table C3-3 (contd.)

Parameter	GETSCN Index	Default	Note
First year for time period 1	72	9999	
SO_2 compliance option in time period 2	73	0	See above.
First year for time period 2	74	9999	
SO_2 compliance option in time period 3	75	0	See above.
First year for time period 3	76	9999	
Year dry FGD's become available	77	1980	
Year LIMB becomes available	78	1992	
Pollution control management switch	79	0	0 - Based on economic decisions at unit level, 1 - Uniform SO_2 rollback at all SIP plants, 2 - Futures method, and 3 - Sort method
Effective year for SIP rollback or permit market	80	9999	See above.
Economic Growth Indicators			
Personal Income growth rate over base (PIGR)	81	0	$PI = PI * e^{(PIGR/100*T)}$, where T = IYEAR - IYREXP
Population growth rate over base (POPGR)	82	0	$POP = POP * e^{(POPGR/100*T)}$, where T = IYEAR-IYREXP
Earnings growth rate over base (ERNGR)	83	0	$EARN = EARN * e^{(ERNGR/100*T)}$, where T = IYEAR - IYREXP

Table C3-3 (contd.)

Parameter	GETSCN Index	Default	Note
Employment growth rate over base (EMPGR)	84	0	$EMP=EMP*e^{(EMPGR/100*T)}$ where $T=IYEAR-IYREXP$
Year to begin nonbase economic growth scenario	85	9999	IYREXP in above equations
Year to begin holding economic inputs constant (IYRCON)	86	9999	Base values for personal income, population, earnings, and employment are held constant from year forward.
Fuel Price Indicators			
Oil price growth rate over base (OILGR)	91	0	$OILP=OILP*e^{(OILGR/100*T)}$ where $T=IYEAR-IYREXP$
Natural gas price growth rate over base (NGGR)	92	0	$NGR=NGP*e^{(NGGR/100*T)}$ where $T=IYEAR-IYREXP$
Nuclear fuel price growth rate over base ((NUCGR)	93	0	$NUCP=NUCP*e^{(NUCGR/100*T)}$ where $T=IYEAR-IYREXP$
Year to begin non-base fuel price scenario	94	9999	IYREXP in above equations
Year to begin keeping fuel prices constant	95	9999	
Fuel price indicator pegging (B)	96	1	Fuel price indicator (sectoral demand model) price of natural gas to distillate oil such that price of natural gas must be $\leq B*$ price of distillate oil.

Table C3-3 (contd.)

Parameter	GETSCN Index	Default	Note
Exogenous Demand and Demand Recalibration			
Exogenous demand switch	101	0	0 - endogenous, 1 - exogenous calibration run, 2 - exogenous run with annual recursion, 3 - exogenous run with demand projection "locked" into user-specified growth path.
Exogenous quantities switch	102	0	0 - none, 1 - demand for electricity, 4 - demand for electricity, oils, gas, and coal. Exogenous demand levels are found in data group 17.
Recalibration year	103	9999	See below.
Recalibration quantities switch	104	0	0 - none, 1 - demand for electricity, 4 - demand for electricity, oils, gas and gas, and coal. When option 1 or 4 is selected, the most current levels of demand available in the URGE data base are used. Levels of demand are interpolated between 1980 and the recalibration year. From that year forward, levels of demand are either calculated endogenously or are exogenously specified, depending on the value of GETSCN(101).
Exogenous transfers of power	105	0	0 = Quantity of net power imported/exported remains constant at 1980 level. Transferred power priced at marginal price paid by industrial customers.

Table C3-3 (contd)

Parameter	GETSCN Index	Default	Note
			1 = Quantities and costs of transferred power are obtained from previous MPMS run. 2 = Quantities and costs of transferred power exogenously specified. 3 = Quantities of transferred power exogenously specified; costs computed internally.
End year for coal contracts	106	1990	Target year for all historical coal prices to converge to model coal prices.

Table C3-4
STATE SCENARIO PARAMETERS

Parameter	GETSCN Index	Note
Control Technology		
FIPS code for state	500	
Land use cost, dollars per acre	501	For waste treatment plants; default is $5000.
Reagent cost for wet FGD systems	502	Dollars per ton; default is $7.48 per ton.
Reagent cost for dry FGD systems	503	Dollars per ton; default is $57 per ton.
Reagent cost for LIMB	504	Dollars per ton; default is $7.48 per ton.
Sulfur RSD exemption status in old units	510	Default is 0.
Sulfur RSD exemption status in new units	511	Default is 3.
Sulfur RSD averaging time for old units	512	1-24 hours, 2-30 days, 3-365 days; default is 3.
Sulfur RSD averaging time for new units	513	1-24 hours, 2-30 days, 3-365 days; default is 2.
Emission/Cost Constraints		
State SO_2 emission limit (least-cost dispatching) or cost limit (least-SO_2-emission dispatching)	528	Annual limit in pounds; in dollars if least-SO_2-emission dispatching is chosen.
State NOx emission limit (least-cost dispatching) or cost limit (least-NO_x-emission dispatching)	529	Annual limit in pounds; in dollars if least-NO_x-emission dispatching is chosen.
State TSP emission limit (least-cost dispatching) or cost limit (least-TSP-emission dispatching)	530	Annual limit in pounds; in dollars if least-TSP-emission dispatching is chosen.
State SO_2 permit allocation	540	$/ton

Table C3-4 (contd.)

Parameter	GETSCN Index	Note
SIP rollback under global management strategy 1	541	Fraction
Capacity Planning Data		
Coal steam unit construction cost	560	Default is $770 per KW (1980$).
Light water reactor unit construction cost	561	Default is $1050 per KW (1980$).
Oil to coal unit conversion cost	562	Default is $200 per KW (1980$)
Year nuclear moratorium ends	563	Construction on a nuclear plant must be deferred until this year unless the fraction of total expenses incurred on the plant is greater than the fraction given by GETSCN(564). Default is 1980.
Construction completion fraction for nuclear moratorium	564	See above; default is 0.

The control program also provides a relatively simple way to modify unit-specific data. Subroutine UNCHNG is called annually by BEGNYR for each unit in the inventory. Normally this is an empty routine consisting of a SUBROUTINE statement, a RETURN statement and an END statement. Should the user wish to alter data for an individual unit or a class of units in any year of a simulation, this may be accomplished by inserting the appropriate FORTRAN code in UNCHNG.

3.2.4 Run-Time Diagnostics

The control program provides certain run-time diagnostics beyond those routinely provided by the operating system. Should a segment of the model detect an inconsistent or missing data element or any potential error condition, it may generate a warning message[1] to the user and then inform the control program that an error condition has been flagged. It does so by calling subroutine ERROR with a single argument, ISTOP. When ISTOP is zero, the control program registers that another error has been flagged by the current module and continues execution. When ISTOP is nonzero, the user is notified that a fatal error has occurred and the run is aborted. At the end of each state simulation, the total number of error messages generated by each module is reported in the program log on the standard output file by subroutine ENDSTA.

Each segment of the model may also generate varying levels of intermediate trace data. At the beginning of program execution, the control program reads seven integer values from the standard input file corresponding to the seven components[2] of the model. These seven trace flags are stored in array MTRACE; each ranges in value from 0 to 9. When a module is called, the control program passes the corresponding trace level as the third argument in the call. Normally, this argument will be zero, signifying no trace. Values between 1 and 9 are assigned by each module developer to denote varying levels of intermediate results and are used to test new or revised code, verify new or revised data sets, and help track down errors detected in previous runs.

3.2.5 Special Data Handling

The control program has three special data-handling tasks: escalation of coal prices, escalation of noncoal fuel prices, and annual updating of the various construction schedules.

3.2.5.1 **Escalation of Delivered Coal Prices.** One general housekeeping task performed by the control program is the escalation of delivered coal prices in the unit inventory. For units that were in existence in 1980, detailed coal shipment data were used to identify the source and price of coals consumed. All coal shipments to a plant from an individual AUSM coal supply region were averaged together (quantity weighted) and data on the two most significant coals (in terms of total heating values) were provided in the initial unit inventory.

---

[1] Each module is assigned a specific unit to which all trace data and error messages are written. Demand is assigned to unit 11; plan, to unit 12; comply, to unit 13; dispatch, to unit 14; impacts, to unit 15; finance, to unit 16; and the control program, to unit 17.

[2] Trace flags are read in order for these components: demand (1), plan (2), comply (3), dispatch (4), impacts (5), finance (6), and the control program (7).

For units that come on-line after 1980, the control technology module (Comply) selects an appropriate coal or blend of coals from the data base provided by the coal supply module. The control technology module may also select a new coal or blend of coals for older units if emission regulation changes so dictate.

In 1980, each existing power plant is assumed to burn the coal(s) identified in the inventory file and pay the price(s) listed in that file. It is also assumed that the price(s) of these coals eventually converges to that of a similar model coal from file E6 over a period of approximately 10 years. This reflects the fact that coal contracts are generally valid for periods less than 10 years and that they are renegotiated periodically to more closely reflect market prices. The user may specify the average length of existing coal control.

This assumption was made to avoid two types of problems. Causing historic coal prices to converge to model coal prices will avoid two types of problems. First, if a unit's emission standard were never changed, its coal price would never approach levels paid by new power plants, even after 30 or 40 years. Second, units that pay higher prices in 1980 than those projected by the coal supply module actually save money by switching to a model coal having the same heating value and sulfur content.

The price of coal at an existing plant in year t is calculated as

$$E_t = E_{t-1} + (M_t - E_{t-1}) \;/\; (max(1, N-t+1))$$

where E_t is the price of coal in year t

M_t is the model price of a similar coal in year t

N is the year in which convergence is to occur

Note that the gap between the actual price and the model price is closed at a rate inverse to the number of years remaining in the contract; after the end year for coal contracts is reached, the historic units will have coal prices the same as the coal model price ($E_t = M$).

This method for causing the coal prices to converge was selected because the only knowledge required is the previous year's price at the point in the simulation when the price is updated.

To compute the new average coal price for year t the incremental portions of the escalation formula above are weighted by the consumption for each type coal and added to the previous year's average price. An example should clarify the procedure. Suppose a unit burns 50 percent (by Btu consumption) of coal type A and 25 percent of coal type B. (The remaining 25 percent comes from lesser coals and is ignored in the model.) Further, suppose the average delivered price of coal to the unit in year t-1 was 100 cents per MMBtu. If the type A coal increases by 4 cents in year t and the type B goes up 1 cent, then the control program will increase the average cost of coal to the unit by a weighted average of the two dominant suppliers. The increment will equal $\left(\frac{4 * .50 + 1 * .25}{.50 + .25}\right)$, or 3 cents per million Btu, and the new average price will be 103 cents.

The coal price escalation procedure is applied in subroutine BEGNYR. See Section 3.3.1 for details.

3.2.5.2 **Escalation of Noncoal Fuel Prices**. Noncoal fuel prices in the unit inventory are modified each year to reflect real (noninflationary) increases in delivered prices. The control program subroutine BEGNYR *replaces* the price of each noncoal fuel each year with the current delivered price obtained from exogenous file E7. To avoid a noticeable jump from 1980 historic prices to 1981 derived prices, the noncoal fuel prices are replaced beginning in 1980.

See the description of subroutine GET (Section 3.3.5) for details about the interpolation of projected data from file E7. The description of subroutine BEGNYR (Section 3.3.1) explains how prices are overwritten.

3.2.5.3 **Annual Update of Construction Schedules**. Several modules create and update entries in the four AUSM construction schedules (data group 23, new units; data group 32, retrofit SO_2 control devices; data group 33, retrofit NO_x control devices; and data group 34, retrofit TSP control devices). At the end of each year the control program assures that entries for units or devices that have come on-line in the current year are "deleted," usually by simply updating indices in the free space vectors. See subroutine ENDYR (Section 3.3.3) for a detailed explanation.

3.2.5.4 **Modifying Unit-Specific Data.** Subroutine UNCHNG is called by BEGNYR before fuel prices are escalated. The routine is called each year. UNCHNG has the current state FIPS number and the current simulation year as arguments. Should a user wish to make changes to the inventory, use of these arguments allows state-specific or year-specific changes to be made (see Section 3.3.21 for details about how to use subroutine UNCHNG).

3.3 Procedures

The main program, AUSM, calls a number of other procedures while performing its tasks. Table C3-5 provides a brief synopsis of each of the 23 subroutines and function subprograms. In addition to these procedures, a nonexecutable block data subprogram is used to initialize variables in named common blocks.

The remainder of this section provides a detailed description of each AUSM procedure included in the control program.

3.3.1 Subroutine BEGNYR

Called by:	AUSM at the beginning of each simulation year.
Calls:	GET, UNCHNG, LENGTH, MMFCAT, G70ACC.
Arguments:	None.
Tasks:	1. Implements user-specified changes in (R)NSPS standards in current year. 2. Calls UNCHNG to implement user changes to unit inventory. 3. Escalates the delivered cost of all fuels for each active unit in the inventory. 4. Writes data for Reports 205, 703, and 705.
Method:	The user may override the default (R)NSPS emission limits in the simulation. These scenario-dependent values are read from exogenous file E8 in subroutine STATE and are stored into array RNSPS in /CTCOM/. BEGNYR simply transfers the appropriate items from RNSPS into array DG31 if the corresponding compliance year is the same as the current year.

Table C3-5
SYNOPSIS AND CALLING SEQUENCE OF CONTROL SUBPROGRAMS

Subprogram	Synopsis	Called by
AUSM	Main program, traffic controller	
BEGNYR	Retrieves scenario-specific changes to the (R)NSPS standards in the current year, calls UNCHNG, and escalates all fuel prices in the unit inventory Reports fuel prices (Reports 703,705) and system retirements (Report 205)	AUSM
ENDSTA	Prints summary run statistics for a state and closes out files E10, E6	AUSM
ENDYR	Updates all construction schedules (Data Groups 23, 32, 33, and 34) at the end of each year by deleting entries that have come on-line Produces trace of construction schedules if requested Reports capital costs for construction (Report 710)	AUSM
ERROR	Records number of error messages written by each module and causes a program abort when a fatal error occurs	All modules
GET	Retrieves full data groups for modules	All modules
GETSCN	Returns scenario parameters	All modules
GETSTA	Converts FIPS code to state name	STATE
GLOBAL	Performs global housekeeping tasks: o Reads trace levels from input file o Opens files for input/output. o Reads global scenario parameters o Reads global demand data o Reads global planning data	AUSM

Table C3-5 (contd.)

Subprogram	Synopsis	Called by
	o Reads global finance data o Reads global fuel data o Reads global MPMS data o Reports global scenario parameter (Report 000) and pollution control parameters (Report 300)	
G23ACC	Accesses data group 23, the new unit construction schedule; creates new entries on request	GET,SGET, PUT,SPUT
G70ACC	Accesses data group 70, the unit inventory; creates new entries on request	BEGNYR,GET,SGET,SPUT
IOERR	Flags I/O errors detected within control program subroutines	GET,SGET, PUT,SPUT
LENGTH	Returns current length of variable length data groups (23, 32, 33, 34, and 70)	All modules
MMFCAT	Converts received HHV to moist-mineral-free HHV category	BEGNYR, pollution control modules
OPENIO	Accesses files (installation dependent)	GLOBAL
PROJ1	Returns interpolated annual value from series of projected values	GET
PUT	Replaces full data sets for modules	All modules
RTROAC	Accesses retrofit construction schedules (data groups 32, 33, and 34); creates new entries on request	GET,SGET, PUT,SPUT
SGET	Retrieves selected subsets of data groups for modules	All modules
SPUT	Replaces selected subsets of data groups for modules	All modules

Table C3-5 (contd.)

Subprogram	Synopsis	Called by
STATE	Performs certain data initializations when a new state is invoked: o Reads state-specific scenario parameters o Reads state coal prices for data group 71 o Positions E6 file to state coal characteristics o Reads state alternate fuel characteristics o Reads projected alternate fuel prices for Data Group 74 o Reads projected demand data for new state o Reads MPMS state data o Reports state scenario parameters (Report 001) o Reports state (R) NSPS standards o Loads unit inventory for new state	AUSM
UNCHNG	Called by BEGNYR; modifies individual entries in unit inventory to implement unit-specific scenario changes (must be altered and recompiled before each altered scenario run); default subroutine has no statements that can be executed	BEGNYR
UNSCNR	Reads external coded unit inventory file and initializes the two binary working files used to store state unit inventory Initializes all pointers used to access data group 70. Zeroes compliance coal data items for use by comply module.	STATE

Annual prices for fuels other than coal delivered to this state are obtained directly from data group 74. Noncoal delivered fuel prices in the inventory are simply overwritten each year by the new values thus obtained. Alternate (noncoal) fuel prices are stored in array OTHPRC.

Delivered coal prices are not escalated in the first year of simulation. In following years the delivered price for coal is escalated using model prices from E6 and kept in array CPRICE. For each projection year, and for each coal type (URGE or EIA SO_2 categories and higher heating values), CPRICE contains the price for the interval indicated by projection year. BEGNYR determines the projection year interval, coal type for first and second coals (if a blend), and increments to be used. The new escalated price for the unit is calculated as the sum of proportionate increments contributed by the change in price for the first and second coals:

$$\text{PRCOLD} + (\text{BTU1}*\text{ESC1} + \text{BTU2}*\text{ESC2})/(\text{BTU1} + \text{BTU2})$$

where PRCOLD is the previous year price, ESC1 and ESC2 are the increments in price for first and second coals, and BTU1 and BTU2 are the proportions of first and second coals contributions to the blended coal. BTU1 plus BTU2 may not always equal 1.00, and if the coal used is not a blend, BTU1 = 1.00, BTU2 = 0.00.

The raw data needed to produce Reports 205, 703, and 705 are collected and written to unit 10 following the procedures specified in the system design document [2].

3.3.2 Subroutine ENDSTA

Called by:	AUSM.
Calls:	GETSCN, ERROR.
Tasks:	Prints summary statistics at end of state simulations. Positions external files E10 and E6 to the next state in the files.
Notes:	Timing estimates are optionally printed if available at the user's installation.

3.3.3 Subroutine ENDYR

Called By:	AUSM.
Calls:	None.
Argument:	Input

IYRDEL - Decision year for removal of unit from construction schedules.

Tasks:

1. Removes entries from construction schedules (data groups 23, 32, 33, and 34) when units or devices come on-line.

2. Optionally prints construction schedules to control program trace file.

3. Writes data for Report 710, capital expenditures.

Method:

At the end of each year, units that have come on-line are deleted from construction data groups. If the unit deleted was in core, its space in core is filled by an overflow unit from disk. The appropriate index (INDX23 or IDXRT) is updated and the space (either on disk or in core) is freed in array LSPA23 or LSPART. See Section 3.2.2.2 for a more detailed discussion of the internal construction schedule representations.

If ITRACE is greater than or equal to one, the number of entries in each schedule is printed to the control program trace file. If ITRACE is three or greater, the complete schedules (prior to deletions) are also printed to unit 17.

The raw data needed to produce Report 710, are collected and written to unit 10 following the procedures specified in the design document [2].

3.3.4 Subroutine ERROR

Called by: All modules and subroutines.

Calls: None.

Argument: ISTOP - Abort flag.

Tasks:

1. Counts error messages.

2. Aborts if fatal error is detected.

Method:

When a module detects a condition that it wants to flag as an error, it writes an error or warning message to the appropriate output file (see the design document [2] for details) and calls ERROR.

ERROR identifies the calling module by the value stored in variable IMOD in common area /CONTRL/ and keeps a cumulative total in array IERR(7) in common area /CERROR/.

If argument ISTOP is zero, no further action is taken. If the calling module considers the error condition fatal, it places a value of 1 in ISTOP; routine ERROR prints a final message to the standard output file and halts execution.

3.3.5 Subroutine GET

Called by: All modules.

Calls: ERROR, GETSCN, G23ACC, G70ACC, IOERR, PROJ1, RTROAC.

Arguments:

Inputs

IGROUP - Data group.

IS - State.

IY - Year.

IENTRY - Entry.

Outputs

VLIST - Transferred data.

Task: Retrieves full data sets.

Method: The usual method of responding to a request for data is simply to transfer the data from the permanent data group storage area into VLIST. The special cases are described below.

Data group 11 consists of global demand data that vary by year. These data are derived by interpolation using the values stored in array VGNAT and the years contained in vector IGNAT. Subroutine PROJ1 performs the interpolation.

Data group 12 is read directly from external file E1 in first simulation year.

Data group 13 returns annual state demand data. As in data group 11, a fixed number of projected values are provided exogenously, and routine PROJ1 is invoked to perform the necessary interpolation. Values are held in array VGBEA and years are stored in IGBEA. After interpolation, four values--income, population, earnings, and employment--are scaled according to the scenario growth parameters, known as the economic growth indicators. These growth parameters are returned by GETSCN(81 to 84) and applied only if GETSCN(85), the year to begin nonbase growth, has been reached. Furthermore, the first four values in data group 13 will remain constant after the year specified by GETSCN(86) is reached.

Data group 16 is read directly from external file E1 in the first simulation year.

Data group 18 returns adjustments to demand model intercepts during annually recursive demand (GETSCN(101)==2) by directly reading from external file E10 in each simulation year.

Data group 20 is read directly from external file E2.

Data group 21 is read directly from external file E2 only if accessed by PLAN.

Data group 23 contains information about units planned or under construction and is accessed by calling a specialized routine named G23ACC.

Data group 30 is read directly from external file E3.

The retrofit schedules, data groups 32, 33, and 34, are accessed by calling RTROAC.

Data group 70 is the unit inventory. It is accessed by calling G70ACC.

Data group 72 returns the physical characteristics for coal type IENTRY in the projection year IY. IENTRY is computed as a function of number of sulfur values and higher heating values for the coal type by the calling routine. IY is a projection year sequence number from 1 to number of projections in E6. Because the coal file is so large, data for only one projection year are kept in core at any given time. These data are stored in array CCHAR(40,4) and the nth row contains physical data for the nth coal.

Variable INCORE denotes the projection sequence currently in core and also the relative record at which the E6 file is positioned. Since the physical coal data are stored by ascending projection year, one record per projection, the GET routine simply positions the file forward or backward an appropriate number of records if INCORE does not equal IY and reads the required data into CCHAR. It then transfers the IENTRY row into VLIST.

Data group 74 contains alternate fuel prices. These prices are derived by invoking subroutine PROJ1 to interpolate from the values and years stored in arrays PRICE and NFYRS, respectively. The prices for oils, natural gas, and nuclear fuel are then scaled according to the scenario parameters referred to as the fuel price indicators. These growth parameters are returned as GETSCN(91 to 93) and are applied only if GETSCN(94), the year to begin nonbase growth, has been reached. The delivered cost of "other" fuels is considered to be negligible and is set to zero. Furthermore, these prices will remain constant after the year specified by GETSCN(95) is reached.

3.3.6 Function GETSCN

Called by:	All modules.
Calls:	None.
Argument:	KEY.
Task:	Returns specified scenario parameter.

Method: KEY is the index to array PARAM. Values less than 500 are reserved for global parameters, while indices over 500 refer to state-specific values. (See the design document [2] for a complete list of scenario parameters.)

Note: Subroutines GLOBAL and STATE read the global and state-specific scenario parameters from exogenous file E8 and store them into array PARAM in common area /SCENAR/.

3.3.7 Subroutine GETSTA

Called by: STATE.

Calls: None.

Arguments: IFIPS, NAME.

Task: Converts an FIPS code (IFIPS) into a 16-character name (NAME).

3.3.8 Subroutine GLOBAL

Called by: AUSM.

Calls: ERROR, GET, OPENIO.

Arguments: None.

Tasks: Performs global "housekeeping" tasks:

1. Reads trace parameters from standard input file.
2. Opens files.
3. Reads global scenario parameters.
4. Reads global demand data.
5. Reads global planning data.
6. Reads global finance data.

7. Reads global fuel data.

8. Reads global MPMS data.

9. Writes data required for Reports 00 (global scenario variables), 300 (exogenous control technology parameters), and 700 (coal data parameters).

Method: Scenario, demand, planning, finance, fuel data, and MPMS data are read from disk files E8, E1, E2, E4, E6, E7, and E9, respectively. Access to data group 30, Exogenous Control Technology Variables, is via a call to GET. Data are written to unit 10 for Reports 00, 300, and 700.

Note: GLOBAL also prints a log header to standard output identifying the version of the model, the scenario being executed, the date, and the individual module trace levels.

Error Conditions: If key values read from E6, E7, or E8 do not match expected values, the program will abort with a call to ERROR.

3.3.9 Subroutine G23ACC

Called by: GET, SGET, PUT, SPUT.

Calls: ERROR.

Arguments:

ISTATE - State.

IENTRY - Key to sequential unit in construction schedule.

NITMS - Number of items selectively to be accessed. On NITMS = zero, a full GET or PUT is carried out.

ITMLST - List of item identifiers used on selective GET/PUTs.

VLIST - Array of values for items transferred.

IGTPUT - Integer flag indicating either GET or PUT:

1 - GET

2 - PUT

Tasks: Accesses data group 23, new unit construction schedule. Does full or selective GET/PUT. Increments the schedule when a new unit is added.

Array Variables:

BUFFER - Vector of unit data for writing to, or reading from, direct access disk files.

CNDFLT - Vector of default values for new entries.

INDX23 - Vector index keys sequential orders of units to locations of data in core or on disk. INDX23(I) gives location of Ith unit.

LSPA23 Vector of locations of data used to keep track of space:

$= 0$ - location is available

$\neq 0$ - location is in use

NGRPST - Two-dimensional array holding state-by-data group lengths accessed by LENGTH function.

DG23 - Two-dimensional array holding construction data in memory.

Storage Variables:

IREC - Direct access record number.

LOC - Location of Ith unit.

LOCMAX - Maximum number of locations (i.e., units) in schedule.

LOCNXT - Initial DO variable for finding free space on disk.

NCOR23 - Maximum number of units in memory. Overflow units are written to disk.

NSCHED - Number of units currently in construction schedule.

NVCNST - Number of items per unit.

Method: Each construction schedule is an indexed sequential access method data set using a fixed amount of core and a direct access disk file to hold overflow entries. A block of memory, DG23, is reserved for the new unit construction schedule. Initial units are placed in DG23 in sequence, beginning at DG23(1,1),(1,2) and continuing to (1,NCOR23). INDX23(I) is filled with the location (second subscript of DG23) and LSPA23(LOC) is set $\neq 0$. Overflow units are written unformatted direct access to disk in records 1 to LOCMAX-NCOR23. At the end of each year, the routine ENDYR deletes units that have come on-line, frees space on disk by filling in core, and updates INDX23 and LSPA23. In following years, when a new unit is added, IENTRY=0 in

CALL, LSPA23 is scanned to find an available location (LSPA23(LOC)=0). The new unit is placed in DG23(1,LOC) in memory, or in record LOC-NCOR23 on disk.

INDX23(IENTRY)=LOC keys the unit sequence number to its location, and LSPA23(LOC)=IENTRY flags the location as being in use. Defaults are inserted and there is a transfer to the GET/PUT procedures test on IGTPUT. If NITMS=0, a full GET or PUT is performed. If NITMS≠0, a selective GET or PUT is performed.

Note: If IENTRY = zero, a new entry is created with default values of 8888 in item 3 (year construction begins) and 9999 in item 4 (year on-line). All other values are set to zero. An attempt to exceed the value of LOCMAX will abort with a call to ERROR.

3.3.10 Subroutine G70ACC

Called by: GET, SGET, PUT, SPUT, BEGNYR.

Calls: None.

Arguments:

ISTATE - State.

IYEAR - Year.

IUNSEQ - Key to sequential unit in unit inventory (data group 70).

NITMS - Number of items to be selectively accessed; on NITMS = zero, a full GET or PUT is carried out.

ITMLST - List of item identifiers used on selective GET/PUTS.

VLIST - Array of values for items transferred.

IGTPUT - Integer flag indicating either GET or PUT:

1 - GET

2 - PUT

Tasks: Accesses data group 70, the unit inventory. Does full or selected GET/PUT. Increments data group 70 when a new unit is added.

Variables:

IRECT - Temporary record number.

IUNCOR - Sequential unit number in core block.

I70CHG - Flag to indicate change to data group 70:

= 0 - no change

≠ 0 - changes

I70DST - FORTRAN I/O unit reference number for the disk file to which changed data group 70 is to be written (the destination file).

I70REC - Disk record number currently held in core.

I70SRC - FORTRAN I/O unit reference number for the disk file from which data group 70 is to be read (the source file).

NGRPST - Array accessed by LENGTH function.

NUNITS - Number of units in data group 70.

NUPRBL - Number of units per block (record); also maximum number of units in core.

NVR5H - Number of items per entry.

N70REC - Number of records in the disk files.

UNDFLT - Vector of default values for new entries.

UNITS - Two-dimensional array holding inventory data in core.

Method: Subroutine UNSCNR (called by STATE) initializes the data group 70 disk files (I70SRC and I70DST) and leaves the first set of units in core storage. On subsequent calls to G70ACC, the requested unit sequence number is checked to determine if it is already in core. If the unit resides in core, GET/PUT procedures apply. If the unit is not in core, the appropriate record is determined, current core is written to I70DST, intervening records are read/written from/to I70SRC/I70DST, and the appropriate record is left in core where GET/PUT procedures are applied.

If the requested unit is zero (new unit addition), the next available sequence number (NUNITS = NUNITS+1) is found and the LENGTH array NGRPST is updated. The access method described above is carried out *but the default values for a new unit are inserted* before the GET/PUT procedures are applied.

Note: If IENTRY equals zero, a new entry is created with default values of 8888 in item 21 (year on-line) and 9999 in item 22 (year retires). All other values are set to zero.

3.3.11 Function IOERR

Called by: GET, SGET, PUT, SPUT.

Calls: None.

Arguments:
INAME - Name of subroutine in which I/O error occurred.
IGROUP - Data group.
IY - Year.
IS - State.
IENTRY - Entry.
MIN - Minimum value allowed.
MAX - Maximum value allowed.

Function: Displays a detailed message in the control program trace file if an error occurs while a data group is being accessed. Program then aborts with a call to ERROR.

3.3.12 Function LENGTH

Called by: All modules.

Calls: ERROR.

Arguments:
IGRP - Data group.
IST - State.

Task: Returns current number of entries held in variable length data groups.

Method: Searches through list of valid data group identifiers for a match on IGRP and list of valid state identifiers for a match on IST. Returns NGRPST(IGRP,IST).

Notes: Array NGRPST is initialized in subroutine UNSCNR and updated by subroutine G70ACC, G23ACC, and RTROAC.

Error Conditions: Invalid state or invalid data group requested. Only data groups 23, 32, 33, 34, and 70 are known to LENGTH. An error condition causes a message to be printed to the control program trace file and a call to subroutine ERROR to abort.

3.3.13 **Function MMFCAT**

Called by: BEGNYR, pollution control routines.

Calls: None.

Arguments: ICOAL - Coal Source

1 = URGE

2 = EIA.

HHV - Coal higher heating value (as received) (Btu/lb)

SUL - Sulfur content (fraction)

ASH - Ash content (fraction)

Task: Converts received HHV to a moist-mineral-free HHV category.

Note: Uses ASTM D388, "Standards of Gaseous Fuels, Coke and Coal" criteria.

3.3.14 **Subroutine OPENIO**

Called by: GLOBAL.

Calls: None.

Arguments: None.

Task: Accesses required external files.

Note:	**This routine is installation dependent, requiring differing forms of access statements.**

3.3.15 **Function PROJ1**

Called By:	GET.
Calls:	None.
Arguments:	IYR - Year for which data is requested. NGYR - Number of years in projection series. IVG - Vector containing years in series. VG - Vector containing projected data points.
Task:	Returns interpolated value for current year.

3.3.16 **Subroutine PUT**

Called By:	All modules.
Calls:	G23ACC, IOERR, RTROAC.
Arguments:	*Input* IGROUP - Data group. IS - State. IY - Year. IENTRY - Entry. *Output* VLIST - Transferred data.
Task:	Replaces full data sets.

Method: For most data groups, PUT simply overwrites the current contents of the permanent data group storage area with the contents of VLIST.

For the unit-specific data groups, special handling routines are called. G23ACC is called for data group 23, while RTROAC is called for data groups 32 through 34.

If IENTRY equals 0, a new entry is created and its assigned sequence number is returned in IENTRY.

Notes:

1. At present, no module ever requests a full replacement of data group 70. Should a full replacement of this data group become necessary, a call to G70ACC would be invoked.
2. Array IGPUT contains a list of data groups known to PUT.
3. Array IGLENG contains the corresponding transfer lengths.
4. Only the current state under study (ISTATE) may be requested.

Error Conditions: An invalid group or state request invokes a call to IOERR. The size of VLIST is determined by the values in IGLENG; no error check is made.

3.3.17 Subroutine RTROAC

Called by: GET, SGET, PUT, SPUT.

Calls: ERROR.

Arguments:

ISTATE - State.
IENTRY - Key to sequential unit in retrofit schedules.
NITMS - Number of items to be selectively accessed. If NITMS = zero, a full GET or PUT is carried out.
ITMLST - List of item identifiers used on selective SGET or SPUT.
VLIST - Array of values for items transferred.
IGTPUT - Integer flag indicating either GET or PUT:
1 - GET
2 - PUT

Tasks: Accesses data groups 32, 33, and 34 (retrofit schedules). Does full or selected GET/PUT. Increments the schedule when a new entry is added.

Array Variables:

BUFFER - Vector of unit data for writing to, or reading from, direct access disk files.
RTDFLT - Vector of default values for new entries.
IDXRT - Two-dimensional index; keys sequential orders of units to locations of data in core or on dish. IDXRT(IRET,I) gives location of Ith unit in data group IRET.
LSPART - dimensional array of locations of data used to keep track of space:
$= 0$ - location is available
$\neq 0$ - location is in use

NGRPST - data group lengths accessed by LENGTH function.
NRETRO - Vector array of number of units currently in retrofit schedules.
RTROS - dimensional array holding retrofit data in memory.

Storage Variables:

IGRP - Retrofit data group ID.
IREC - Direct access record number.
IRET - Sequential access to appropriate position in arrays:
  1 - data group 32
  2 - data group 33
  3 - data group 34
LOC - Location of Ith unit.
MAXRTR - Maximum number of locations (i.e., units) in any schedule.
LOCNXT - Initial DO variable for finding free space on disk.
NCORET - Maximum number of units in memory; overflow units are written to disk.
NRTGRP - Number of units in current retrofit schedule.
NVRTRP - Number of items per unit.

Method: Each construction schedule is an indexed sequential access method data set using a fixed amount of core and a direct access disk file to hold overflow entries. A block of memory, RTROS, is reserved for the retrofit schedules. Initial units are placed in RTROS in sequence, beginning at RTROS(IRET,1,1),(IRET,1,2) and continuing to (IRET,1,NCORET). IDXRT(IRET,I) is filled with the location (third subscript of RTROS) and LSPART is set ≠ 0. Overflow units are written unformatted direct access to disk in records 1 to MAXRTR-NCORET. At the end of each year, the routine ENDYR deletes units that have come on-line, frees space on group disk file by filling in core, and updates IDXRT and LSPART.

In succeeding years, when a new unit is added (IENTRY=0 in call), LSPART is scanned to find an available location (LSPART(IRET,LOC)=0). The new unit is placed in RTROS(IRET,1,LOC) in memory, or in record LOC-NCORET on disk. IDXRT(IRET,IENTRY)=LOC keys the unit sequence number to its location, and LSPART(IRET,LOC)=IENTRY flags the location as in use. Defaults are inserted and there is a transfer to the GET/PUT procedures test on IGTPUT. If NITMS is zero, a full GET or PUT is performed. If NITMS is nonzero, a selective GET or PUT is performed.

Note: If IENTRY is zero, a new entry is created with default values of 9999 in item 4 (year on-line). All other values are set to zero. An attempt to exceed the value of MAXRTR will abort with a call to ERROR.

3.3.18 Subroutine SGET

Called by: All modules.

Calls: G23ACC, G70ACC, IOERR, RTROAC.

Arguments: *Input*

IGROUP- Data group.

IS - State.

IY - Year.

IENTRY- Entry.

NVALS - Number of items requested.

ITEMID- Specific item requested.

Output

VLIST - Transferred data.

Task: Retrieves selected subset of data group.

Method: Special handling routines are called for unit-specific data groups. G23ACC is called for data group 23; RTROAC is called for data groups 32, 33, and 34; and G70ACC is called for data group 70. For all other valid data groups, selected items are simply transferred into VLIST in the order specified in ITEMID.

Note: IGGET contains the names of valid data groups. Only the state under study (ISTATE) may be requested.

Error Condition: An invalid state or data group request invokes a call to IOERR. Furthermore, for unit-specific data, IENTRY must lie between 1 and the corresponding maximum shown below:

Data Group	*Maximum Number of Entries*
23	NSCHED
32	NRETRO(1)
33	NRETRO(2)
34	NRETRO(3)
70	NUNITS

3.3.19 Subroutine SPUT

Called by: All modules.

Calls: G23ACC, G70ACC, IOERR, RTROAC.

Arguments: *Input*

IGROUP - Data group.

IS - State.

IY - Year.

IENTRY - Entry.

NVALS - Number of items requested.

ITEMID - Specific items requested.

Output

VLIST - Transferred data.

Task: Replaces a selected subset of a data group.

Method: Only five data groups may be replaced selectively. Special handling routines are called in all cases (G23ACC for data group 23; RTROAC for data groups 32, 33, and 34; and G70ACC for data group 70).

Note: IGPUT contains a list of valid data groups. If IENTRY is zero, a new entry is created and its assigned sequence number is returned in IENTRY.

Error Conditions: Only the current state and a valid data group may be requested. The value passed in IENTRY must lie between zero and one of the maximums shown below:

Data Group	*Maximum Entry Number*
23	NSCHED
32	NRETRO(1)
33	NRETRO(2)
34	NRETRO(3)
70	NUNITS

3.3.20 Subroutine STATE

Called by: AUSM.

Calls: ERROR, GETSCN, GETSTA, UNSCNR.

Arguments: None.

Tasks: Performs certain "housekeeping" tasks whenever a new state is invoked:

1. Reads state-specific scenario parameters,
2. Initialize data group 31,
3. Reads state fuel characteristics and prices for this state,
4. Reads projected demand data and optional external file E10 for this state,
5. Reads financial data for this state,
6. Reads coal prices and increments for this state,
7. Reads MPMS state data,
8. Loads unit inventory for this state,
9. Writes data for Report 01, and
10. Writes data for Report 301.

Method: Scenario parameters are read from external file E8 into vector PARAM beginning at NGPAR (number of global parameters) + 1. (The physical format of file E8 and the other files discussed here, and descriptions of the corresponding internal data groups, are found in the design document [2].) User-specified changes to the (R)NSPS standards for this state are read from E8 and stored in RNSPS. The vector DG31 holds data group 31 is restored to the national defaults for (R)NSPS standards.

The technology build mix fractions are read into data group 26. The exogenous years and demand levels are read to YRS17 and data group 17. Net quantities and costs of power transfers are read to TRNPOW. Data group 19 is also read from external file E8.

The physical characteristics and delivered price projections for fuels other than coal are read from external file E7 and stored in array DG73 and PRICE. Sulfur and ash contents are converted from percentages to fractions.

The data points for the four state-specific demand projection series are read from E1.

State financial data and base-year data are read from E4.

Coal prices are read from E6. The first year coal characteristics are also read from E6.

Subroutine UNSCNR is called to load the state unit inventory.

The raw data needed for Reports 01 and 301, state scenario parameters and (R)NSPS, are written to unit 10 following the procedures specified in the design document.

Note: State data sets are read sequentially from files E1, E10, E4, E6, E7, E8, and E9 until a match occurs on ISTATE.

Error Conditions: If STATE is unable to locate the requested state dataset, an appropriate error message is written to the control program trace file and a program abort is forced by calling ERROR.

3.3.21 Subroutine UNCHNG

Called by: BEGNYR.

Calls: None.

Arguments:

ISTATE - Current state FIPS number.

IYEAR - Current simulation year date.

UNTVAR(NVPRUN)- Array of items from a single unit of data group 70.

NVPRUN - Length of UNTVAR.

Task: Modifies individual entries in unit inventory to implement unit-specific scenario changes.

Method: UNCHNG is a "dummy" subroutine into which a user may insert FORTRAN code. This code will be executed for each unit when BEGNYR accesses data group 70 for fuel price escalations. Any item may be accessed, tested, and changed by the user-inserted code. An example is provided as comments. If no code is inserted, a call to UNCHNG results in an immediate return.

Note: With UNCHNG a user also has access to all common data and may be able to make changes in those data.

3.3.22 Subroutine UNSCNR

Called by: STATE.

Calls: ERROR.

Arguments: None.

Task: Gets state data from exogenous E5 and E5A, puts number of units in LENGTH function array, and blocks generator inventory to source file.

Variables:

IE5ANN(2,51)	- Array read from prologue of disk file E5A.
IE5APT	- Pointer to the next state available from E5A.
IE5HST(2,51)	- Array read from prologue of disk file E5.
IE5POS	- Pointer to next state available from E5.
ISTATE	- FIPS state ID number.
I70CHG	- Flag to indicate change to data group 70: = 0 - no change. ≠ 0 - changes.
I70DST	- FORTRAN I/O unit reference number for the disk file to which changed data group 70 is subsequently written (the destination file) by calls to [S]GET/PUT.
I70REC	- Disk record number currently held in core.
I70SRC	- FORTRAN I/O unit reference number for the disk file from which changed data group 70 is to be read (the source file).
GENRS(72,50)	- Array to hold current block of units
NGENS	- Number of units in data group 70.
NGRPST(5,50)	- Array accessed by LENGTH function.
NHDR5A	- Number of header (comments) records in prologue of E5A; incremented after first read to include IE5ANN records.
NHDR5H	- Number of header (comments) records in prologue of E5; incremented after first read to include IE5HST records.
NUPRBL	- Number of units per block (record); also maximum number of units in core.
NVR5A	- Number of items, values, per unit in E5A.
NVR5H	- Number of items, values, per unit in E5 (and DG70).
N70REC	- Number of records in the disk files.
READ5A	- Logical switch equal true when reading file E5A.
READ5H	- Logical switch equal true when reading file E5.

Method:	**A fixed area of core is reserved to hold blocks of units from the exogenous unit inventory files E5 and E5A. Blocks of NUPRBL units are written binary to disk file, I/O reference number I70SRC (source file for later reading of units from data group 70), as single logical records. A second disk file I/O, reference number I70DST (destination for saving changed versions of data group 70), is prepared. The control program assigns reference number values to I70SRC and I70DST.**

C3.4 Flow Diagrams

This section consists of flow diagrams for six of the subroutines in the control program: BEGNYR, ENDYR, G23ACC, RTROAC, G70ACC, and UNSCNR (Figures C3-5 through C3-9).

Figure C3–5
BEGNYR FLOW DIAGRAM

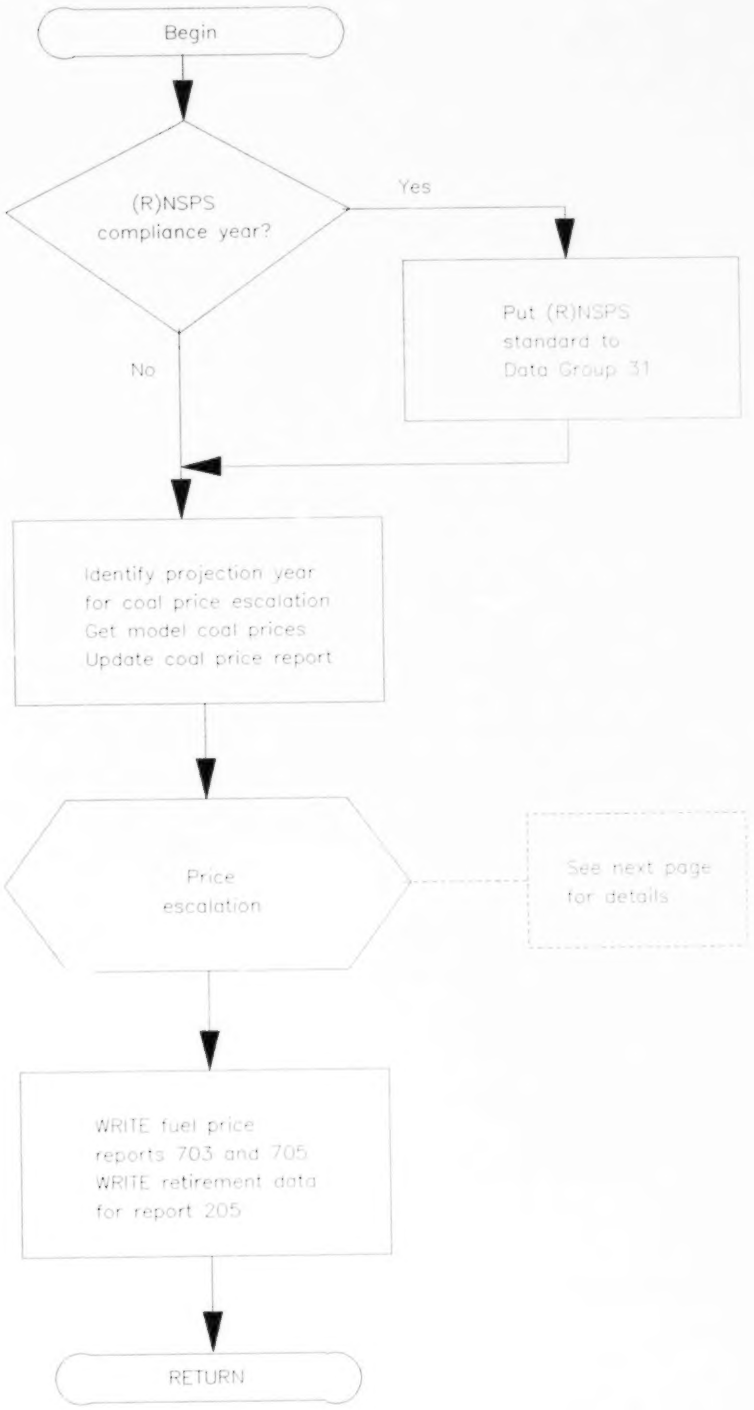


Figure C3–5 (contd.)

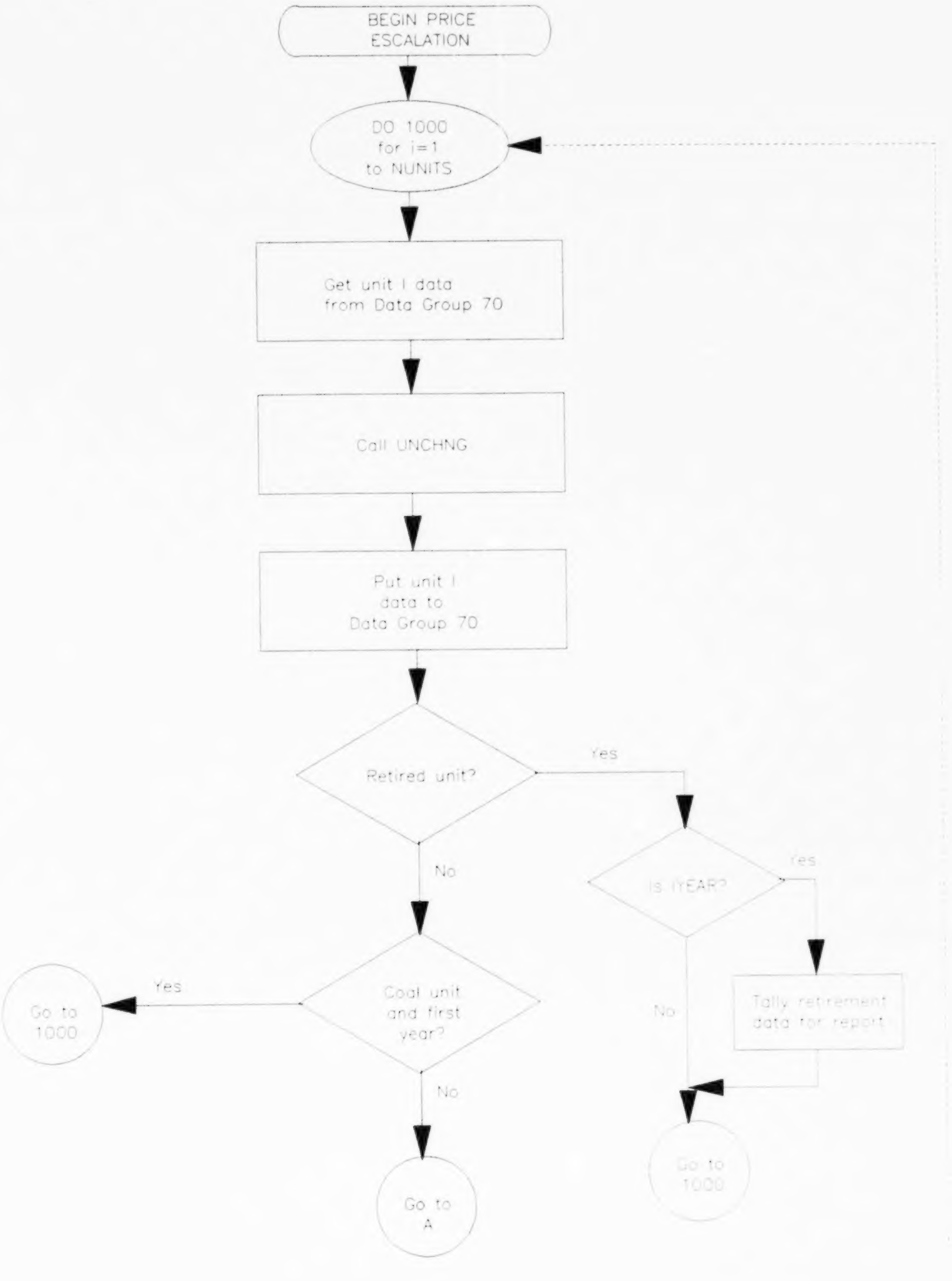

BEGIN PRICE ESCALATION
DO 1000 for i=1 to NUNITS
Get unit I data from Data Group 70
Call UNCHNG
Put unit I data to Data Group 70
Retired unit?
Yes
No
Is IYEAR?
Yes
No
Tally retirement data for report
Go to 1000
Coal unit and first year?
Yes
No
Go to 1000
Go to A

Figure C3-5 (contd.)

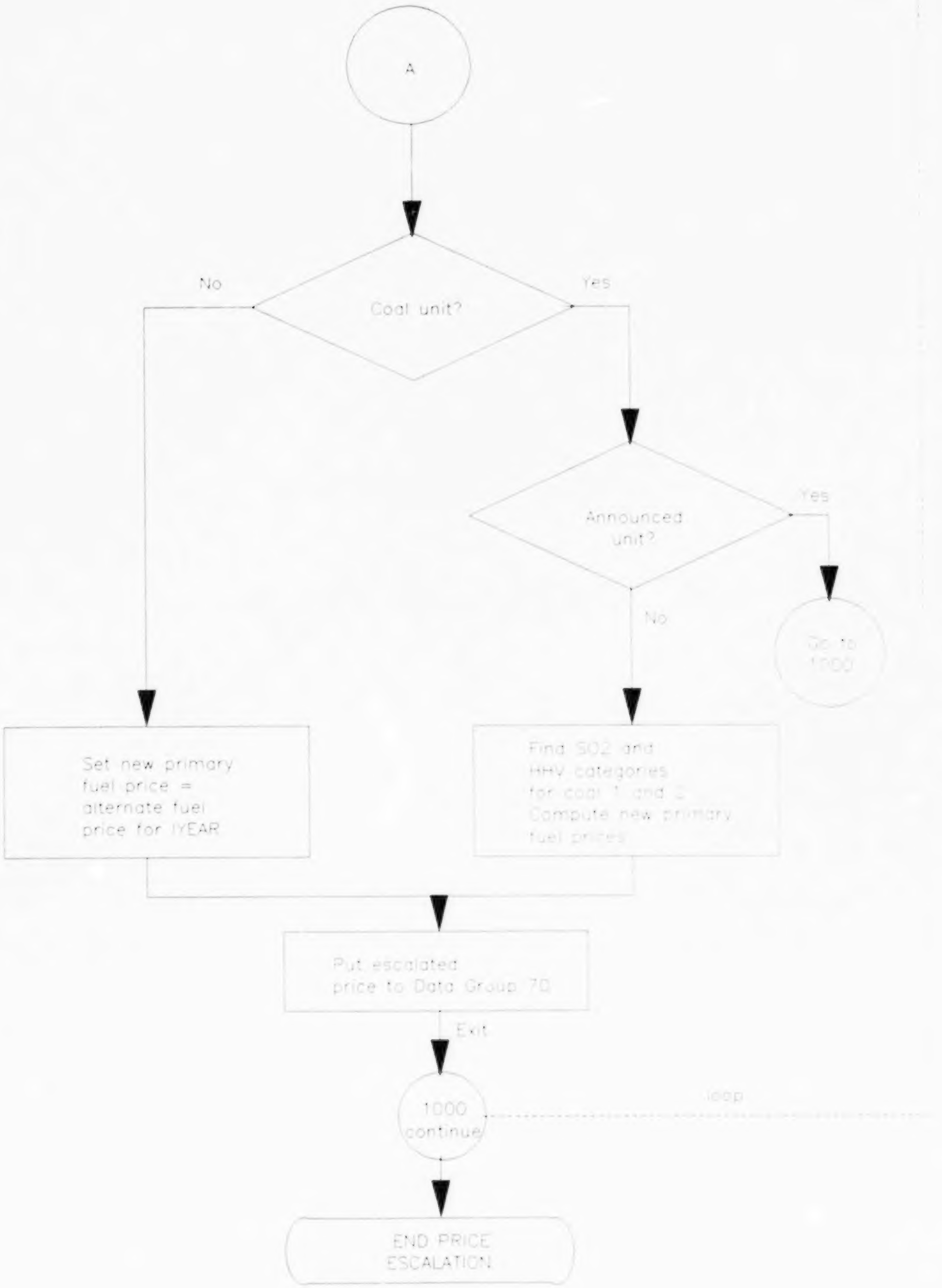

A
Coal unit?
No
Yes
Announced unit?
Yes
No
Go to 1000
Set new primary fuel price = alternate fuel price for IYEAR
Find SO2 and HHV categories for coal 1 and 2
Compute new primary fuel prices
Put escalated price to Data Group 70
Exit
1000 continue
loop
END PRICE ESCALATION

Figure C3–6

ENDYR FLOW DIAGRAM

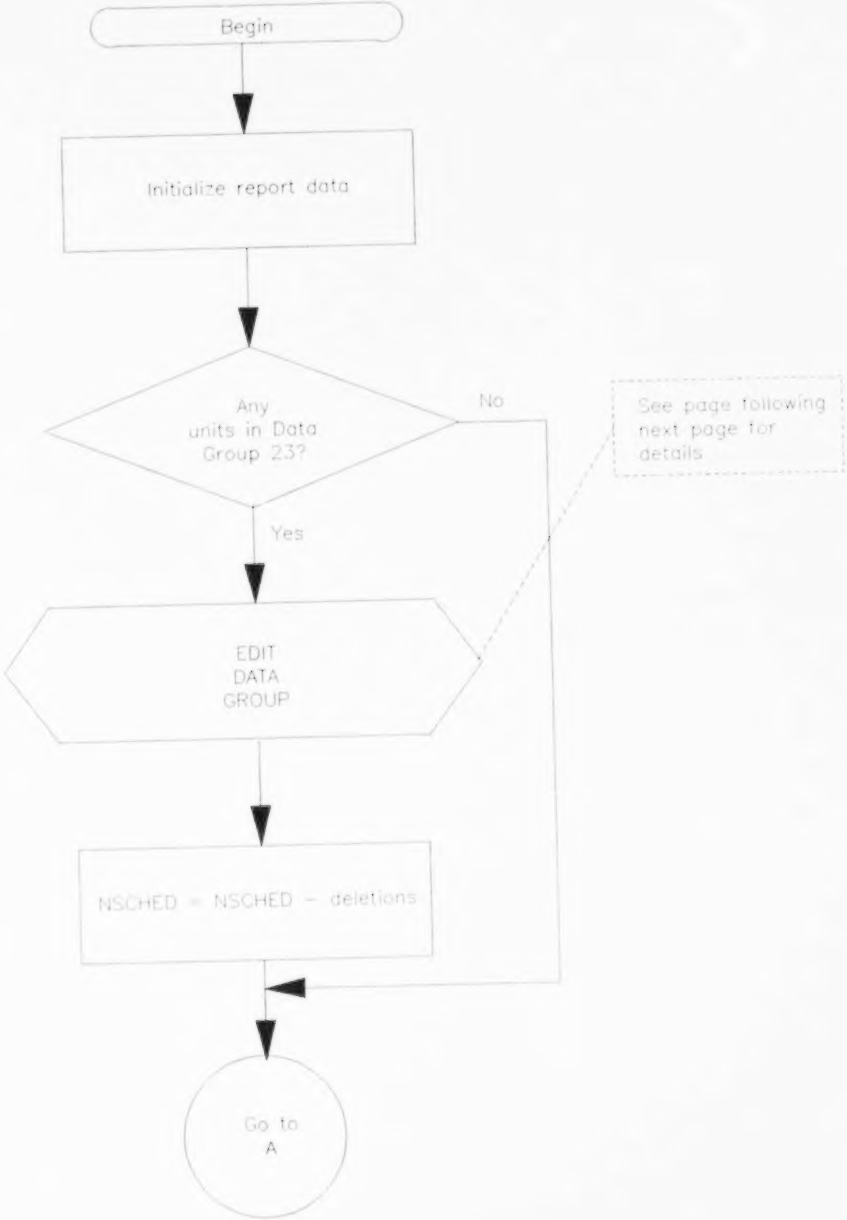

Begin
Initialize report data
Any units in Data Group 23?
No
Yes
See page following next page for details
EDIT DATA GROUP
NSCHED = NSCHED – deletions
Go to A

Figure C3–6 (contd.)

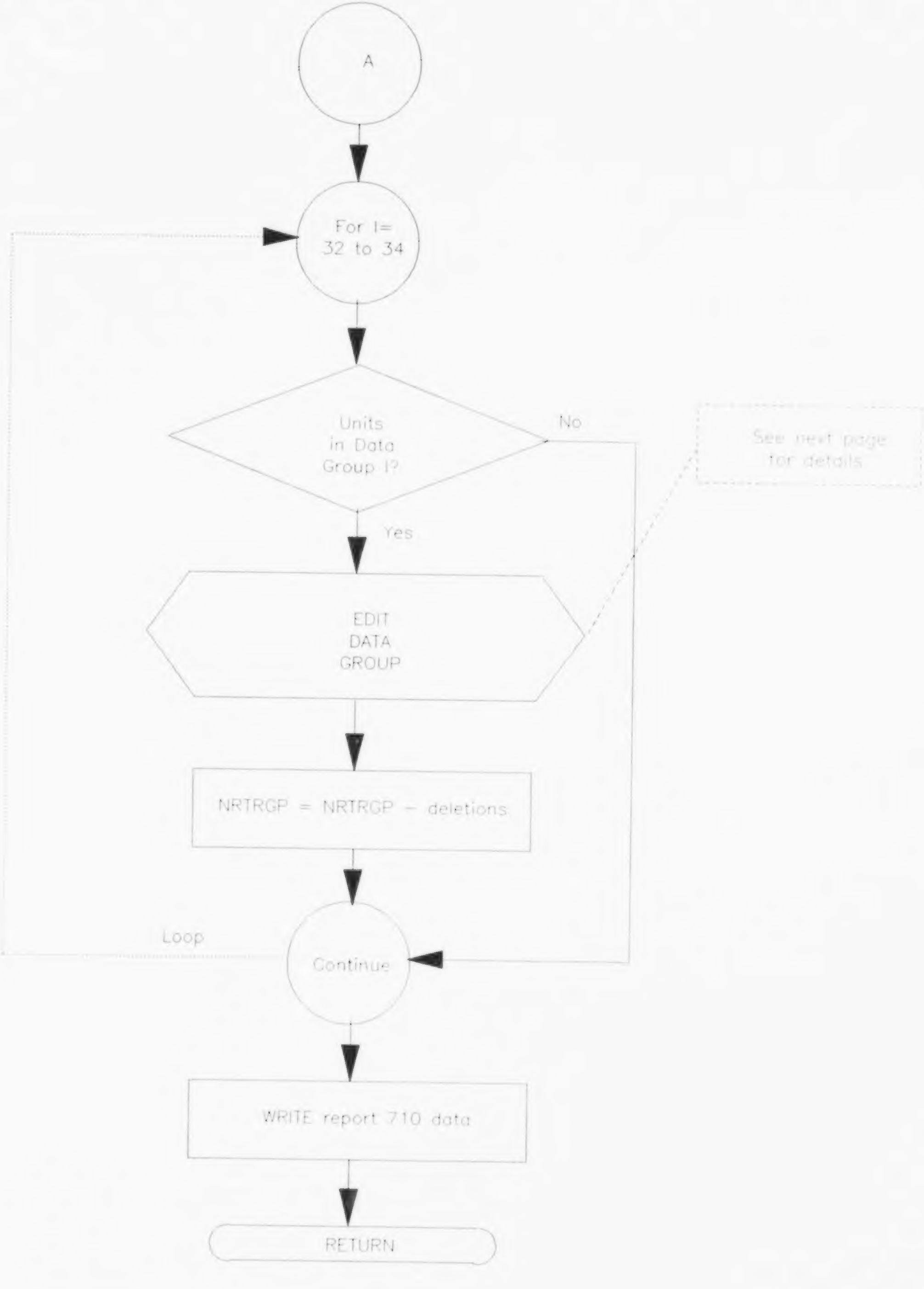


Figure C3–6 (contd.)

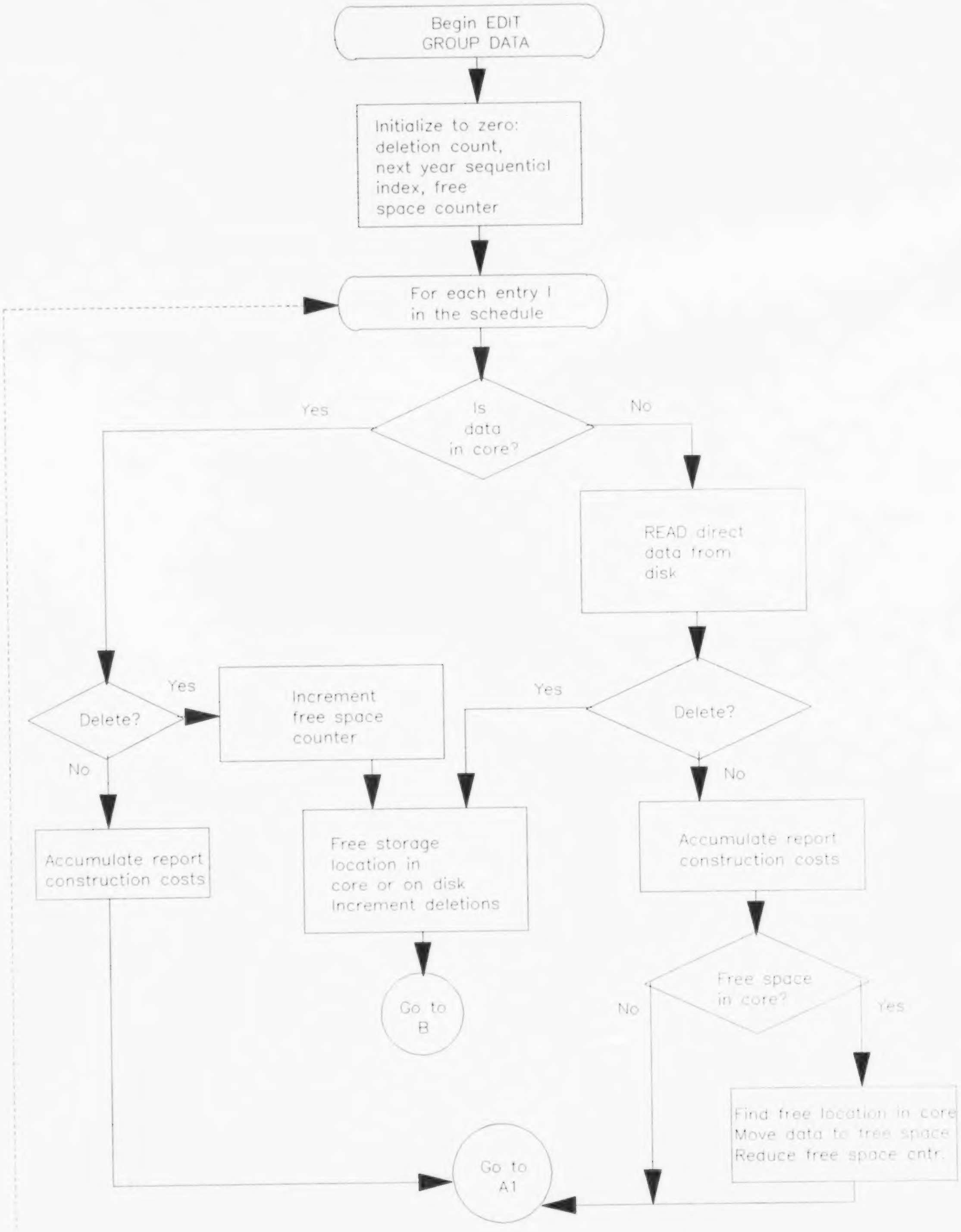


Figure C3-6 (contd.)

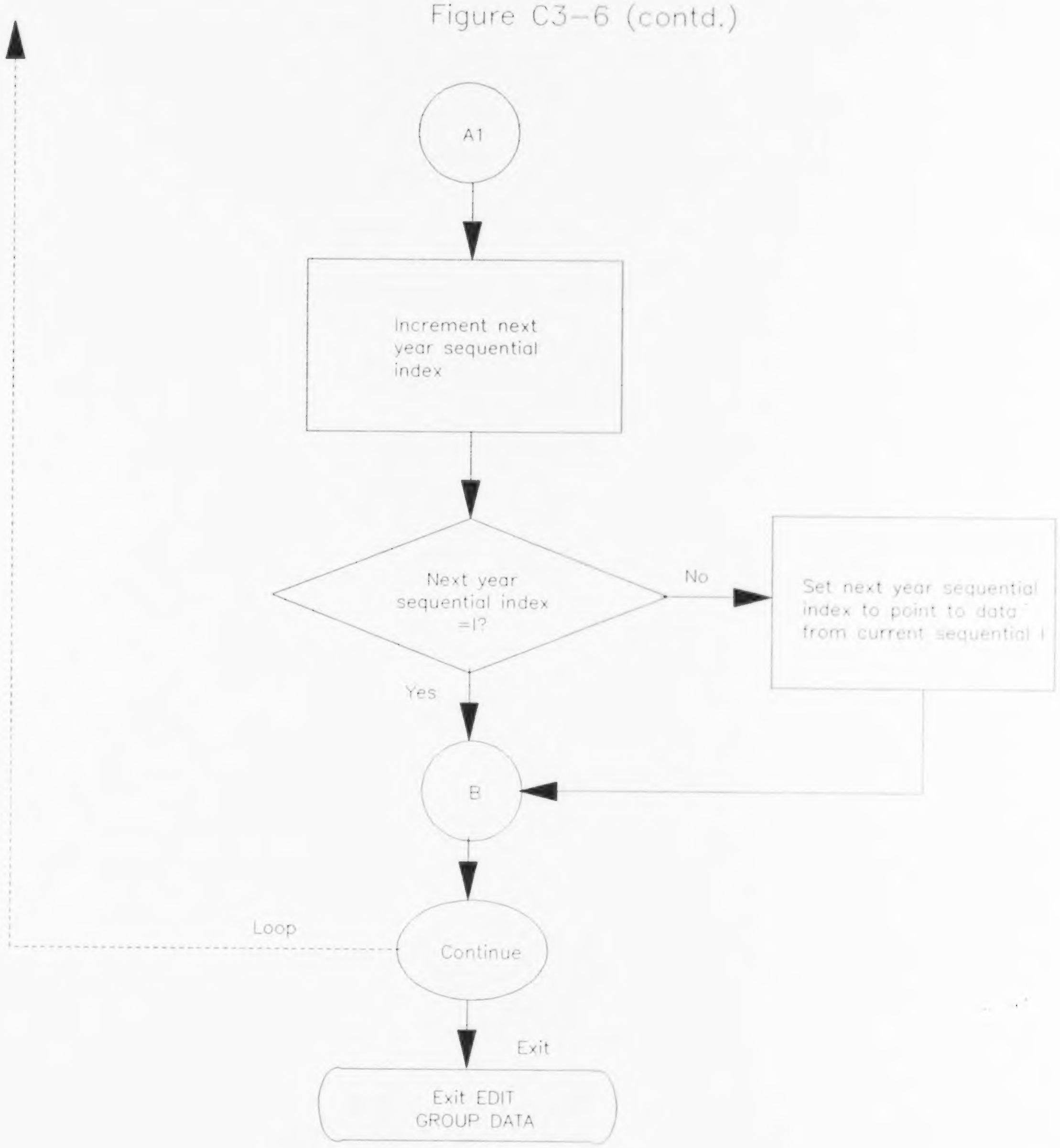

A1
Increment next year sequential index
Next year sequential index =I?
No
Set next year sequential index to point to data from current sequential i
Yes
B
Loop
Continue
Exit
Exit EDIT GROUP DATA

Figure C3-7
G33ACC AND RTROAC FLOW DIAGRAM (CONSTRUCTION SCHEDULES ACCESSING)

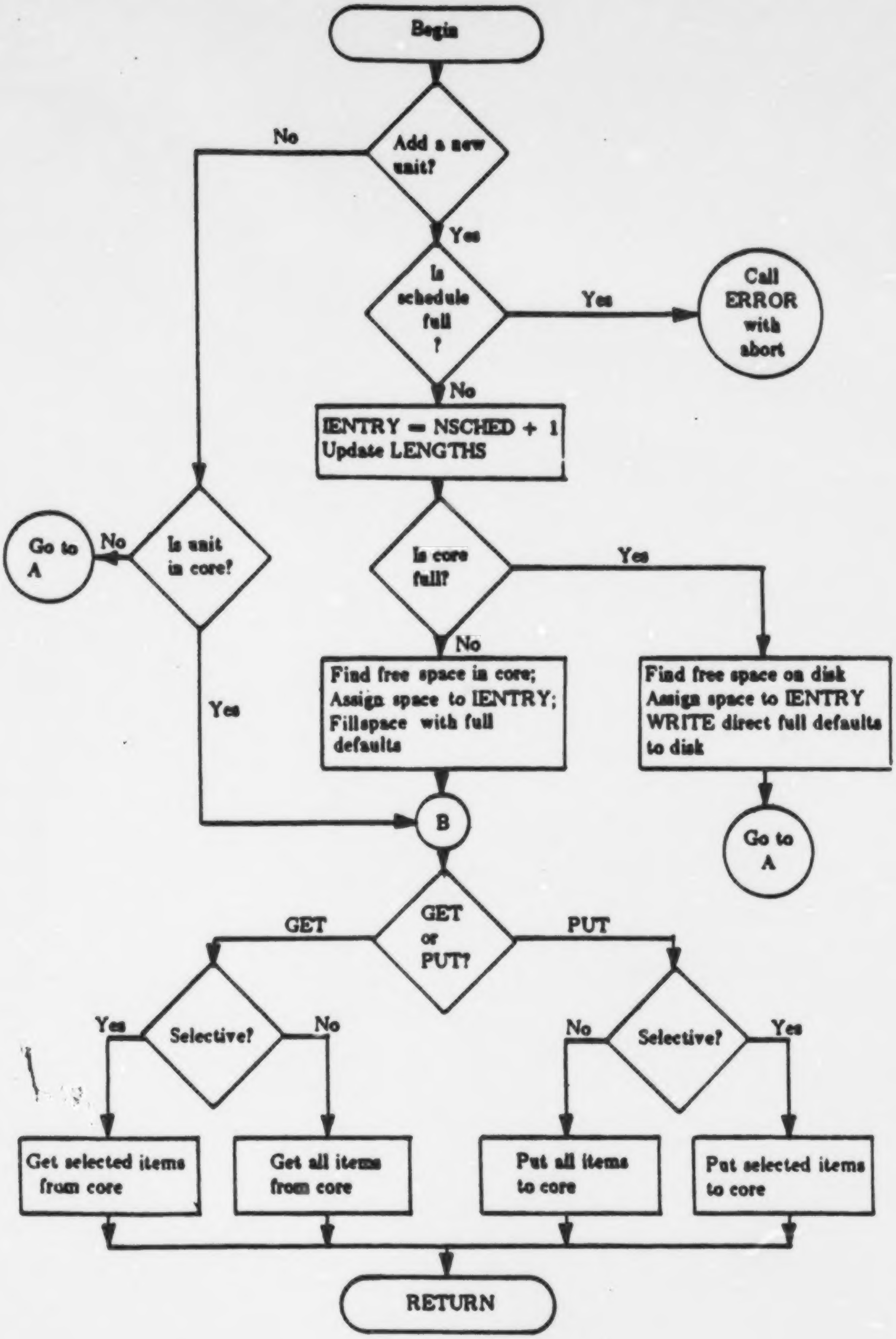


Figure C3–7 (contd.)
G33ACC & RTROAC FLOW DIAG. (CONSTRUCTION SCHEDULES ACCESSING)

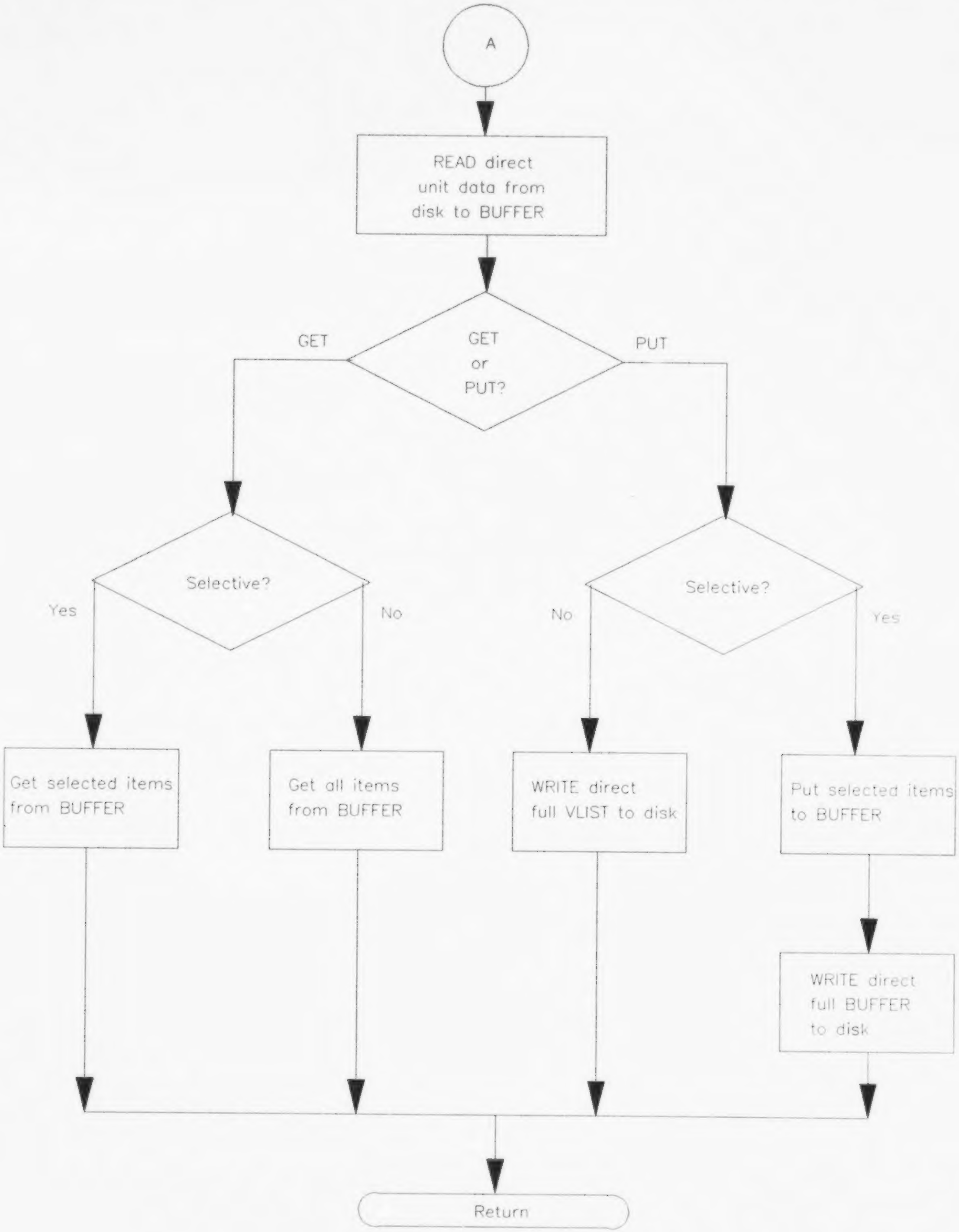

A
READ direct unit data from disk to BUFFER
GET
GET or PUT?
PUT
Selective?
Yes
No
Selective?
No
Yes
Get selected items from BUFFER
Get all items from BUFFER
WRITE direct full VLIST to disk
Put selected items to BUFFER
WRITE direct full BUFFER to disk
Return

Figure C3-8
G70ACC FLOW DIAGRAM

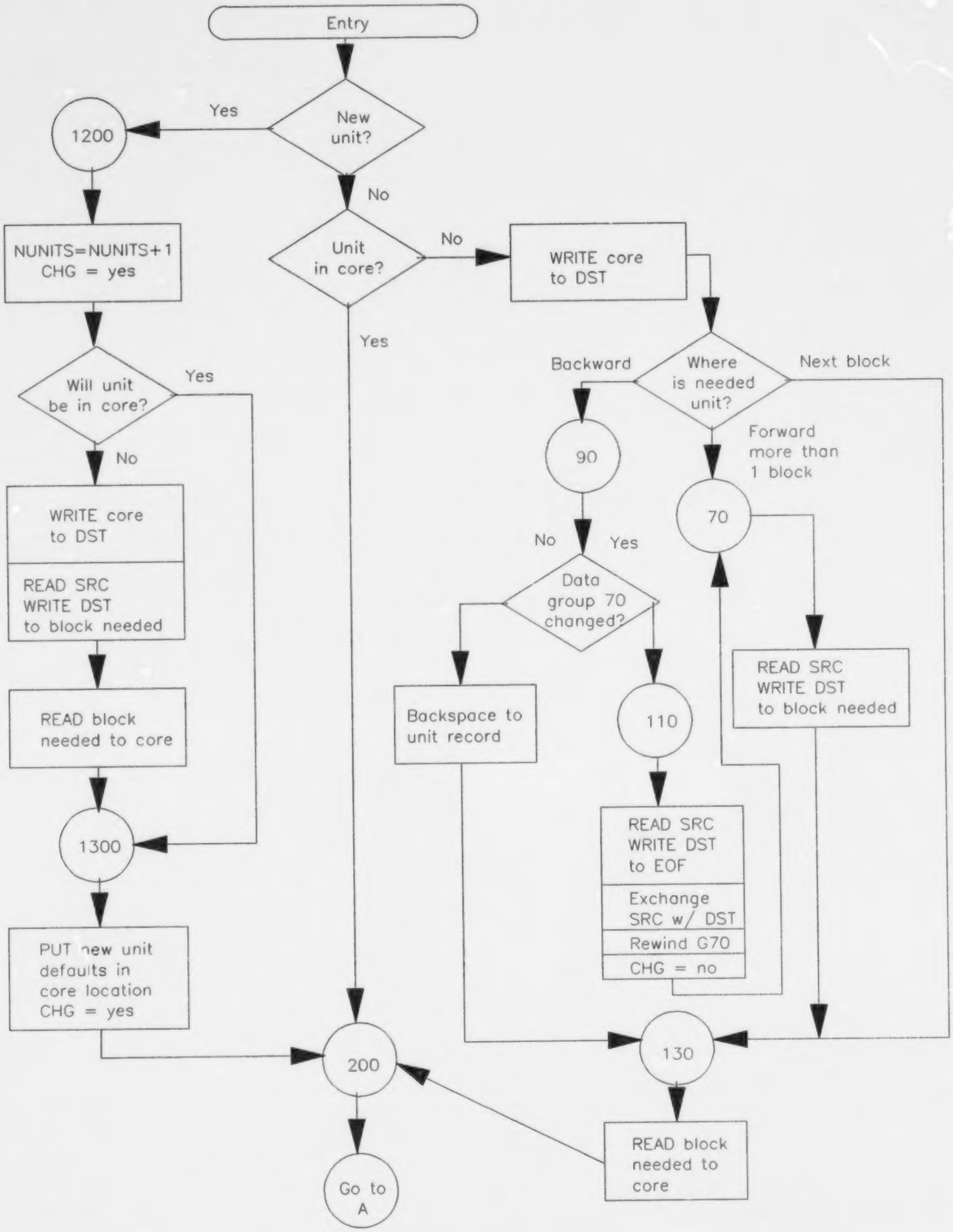


Figure C3–8 (contd.)

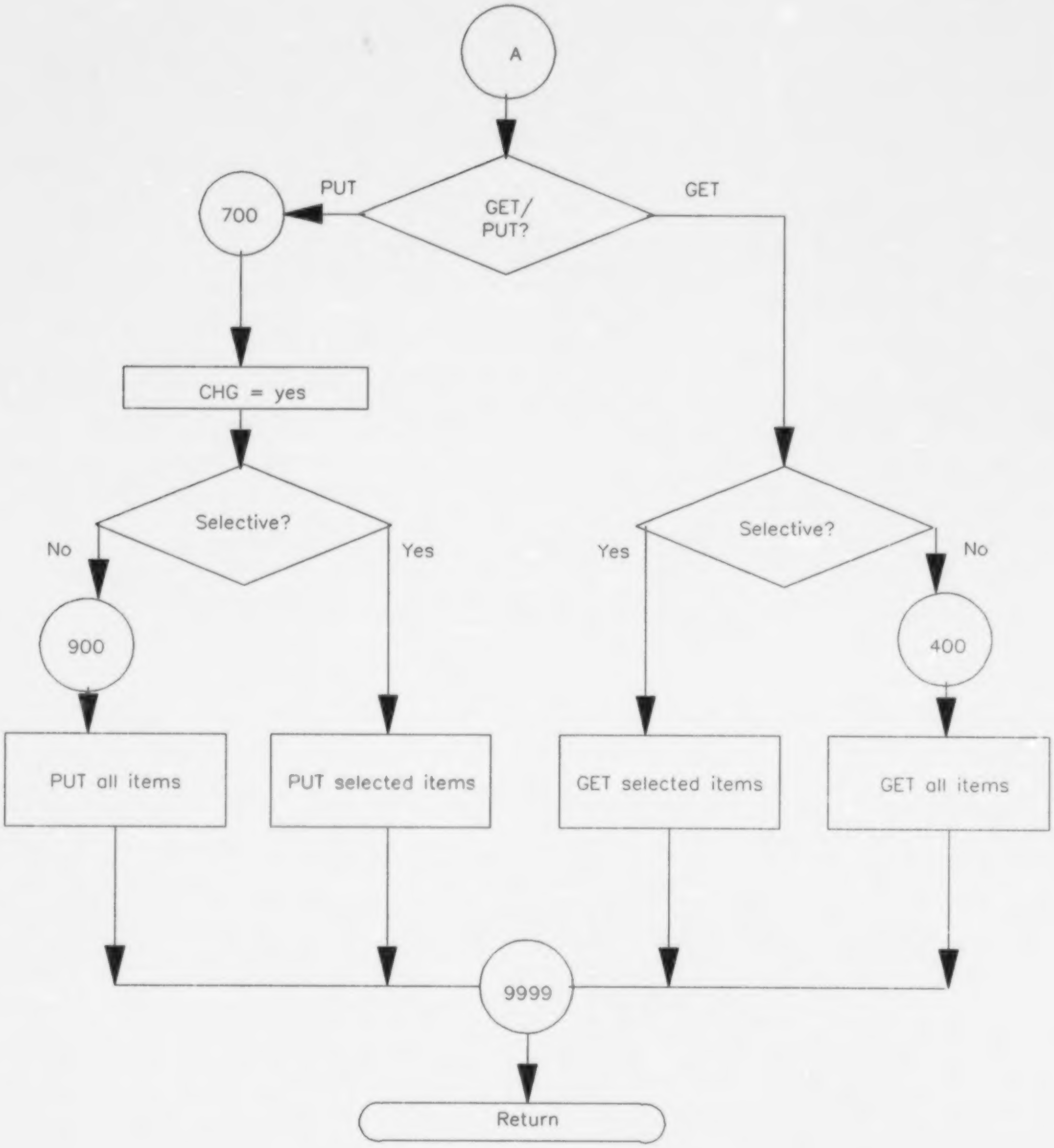


Figure C3-9
UNSCNR FLOW DIAGRAM

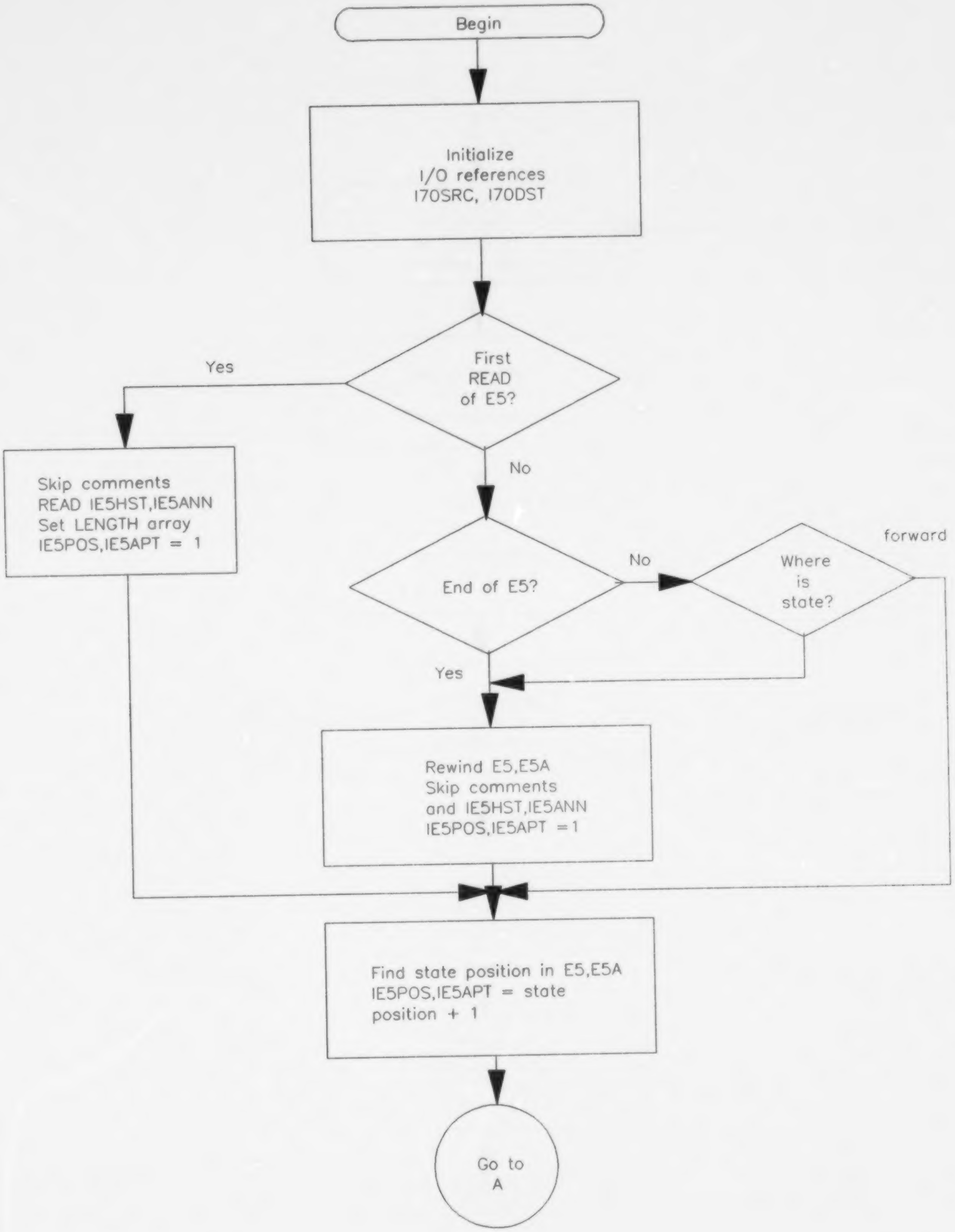
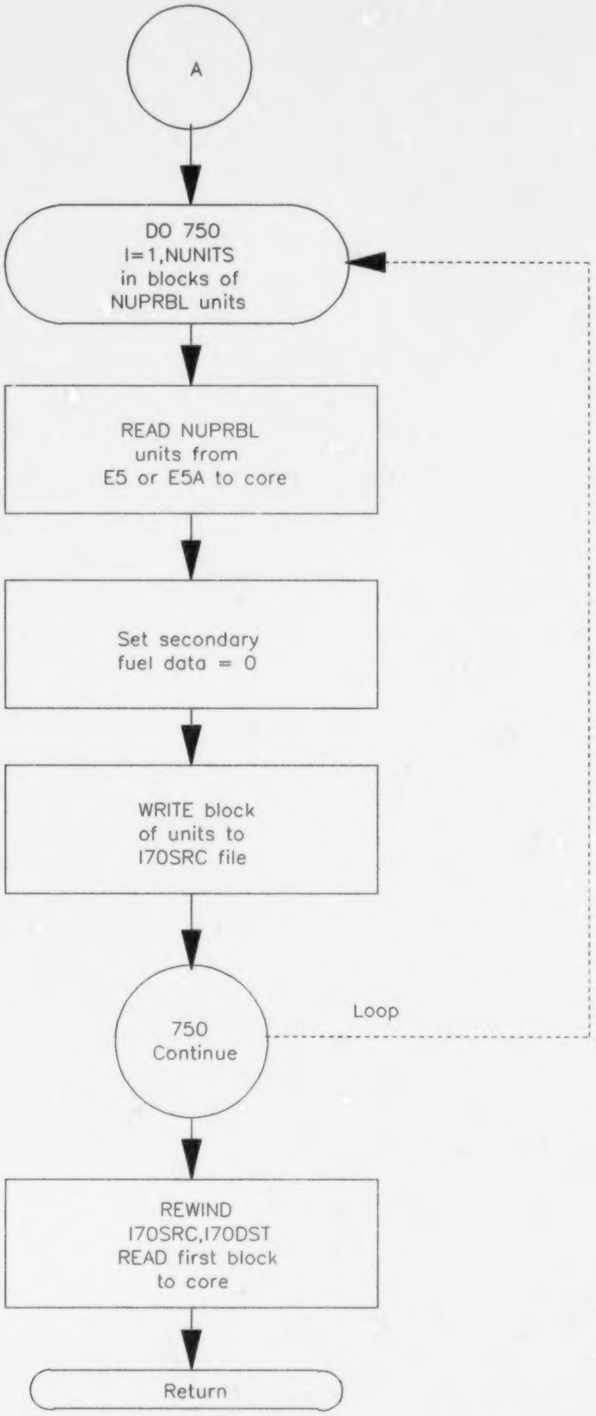


Figure C3-9 (contd.)



3.5 Variable Information

Table C3-6 provides information on the variables included in the control program. It should be noted that the program uses the default variable typing implicit in FORTRAN. A variable name that begins with the letters I, J, K, L, M, or N implies type integer; any other letter implies type real.

Table C3-6
CONTROL PROGRAM VARIABLES

Variable	Dimensions	Description	Location	Accessed by
ASH,ASH1,ASH2		Ash content of average first and second coals		BEGNYR,MMFCAT,STATE
BTU1,BTU2		BTU fractions of first and second coals in a blend		BEGNYR
CCHAR	4	Holds coal physical characteristics for last year accessed	/COAL/	GET,STATE
CNDFLT	23	Default values used to create a new entry in data group 23	/G23/	G23ACC
CPRICE	40,10	Delivered coal prices	/COAL/	BEGNYR,GET,STATE
CYEARS	10	Actual years in coal projection series	/COAL/	BEGNYR,GET,GLOBAL
DG23	23,50	First 50 entries in data group 23	/G23/	ENDYR,G23ACC
DG31	15	Current (R)NSPS	/CTCOM/	BEGNYR,GET,SGET,STATE
DG31IN	15	Initial (R)NSPS		STATE
DGxx	various	Data groups		GLOBAL,STATE,I/O routines
FCODE		Fuel code		BEGNYR
FIPS		State FIPS number		STATE
GENRS	72,50	Current block (record) of unit inventory held in core	/UNINVY/	G70ACC,UNSCNR
HHVAV,HHV1,HHV2		Received HHV for average, first and second coals		BEGNYR
ICOLCT		Coal category: 1 = URGE 2 = EIA	/COAL/	BEGNYR,GLOBAL
IDMDSW		Demand switch (GETSCN(101))		STATE

Table C3-6 (contd.)

Variable	Dimensions	Description	Location	Accessed by
IDXRT	3,100	IDXRT(IRET,j) is location in core or on disk of the jth entry of retrofit schedule IRET	/RETROS/	RTROAC,ENDYR
IEND		Last year of simulation	/CONTRL/	AUSM,ENDYR,ENDSTA, GLOBAL,STATE
IENTRY		Arguments of [S]GET/PUT		All
IERR	7	IERR(IMOD) is cumulative number of error messages issued by module IMOD	/CERROR/	ENDSTA,ERROR
IE5ANN	2,51	FIPS codes, number of units in E5A	/UNINVY/	UNSCNR
IE5APT		Pointer to next state available from E5A	/G70PRM/	UNSCNR
IE5HST	2,51	FIPS codes, number of units in E5	/UNINVY/	UNSCNR
IE5POS		Pointer to next state available from E5	/G70PRM/	UNSCNR
IFIPS		State FIPS number		GETSTA,STATE
IGGET		Valid data groups		GET,SGET
IGLENG		Valid data group lengths		GET,PUT
IGPUT		Valid data groups		PUT,SPUT
IGROUP		Data group identification		GET,IOERR,PUT, SGET,SPUT
IGTPUT		Get/put with: 1 = get 2 = put		G23ACC,G70ACC,RTROAC
IMOD		Active module: 1 = Demand 2 = Plan 3 = Comply 4 = Dispatch		

Table C3-6 (contd.)

Variable	Dimensions	Description	Location	Accessed by
		5 = Impact 6 = Finance 7 = Control Program	/CONTRL/	AUSM,ERROR,GET,IOERR, LENGTH
INAME		URGE IO routine name		GET,IOERR,PUT,SGET,SPUT
INCORE		Projection year index for which coal characteristics data are currently held in core	/COAL/	ENDSTA,GET,GLOBAL,STATE
INDX23	300	INDX23(i) is location in core or on disk of the ith entry in the new unit construction schedule (data group 23)	/G23/	ENDYR,G23ACC
IORET	3	I/O reference numbers for retrofit data files	/IO/	ENDYR,OPENIO,RTROAC
IRET		Identifies retrofit schedule: 1 = data group 32 2 = data group 33 3 = data group 34		ENDYR,GET,PUT,RTROAC, SGET,SPUT
IRID		Report identification		BEGNYR,ENDYR,GLOBAL, STATE
IRPRT		I/O reference number for report file	/IO/	BEGNYR,ENDYR,GLOBAL, OPENIO,STATE
ISTART		First year of simulation	/CONTRL/	AUSM,BEGNYR,ENDSTA,GET, GLOBAL,STATE
ISTATE		Current state (FIPS code)	/CONTRL/	All
ISTOP		Abort flag: = 0 - warning ≠ 0 - abort		ENDSTA,ERROR,GET,GLOBAL, G23ACC,IOERR,LENGTH, RTROAC,STATE,UNSCNR

Table C3-6 (contd.)

Variable	Dimensions	Description	Location	Accessed by
ISUB		Report subindex number		All reporting routines
ITEMID,ITMLST		List of selected data group items		G23ACC,G70ACC,RTROAC, SGET,SPUT
ITRC1-ITRC7		I/O reference number for nth module trace file	/IO/	All tracing routines
IY		Year requested		GET,IOERR,PUT, SGET,SPUT
IYEAR		Current year of simulation	/CONTRL/	All
I1-I10		Variable I/O unit references for disk files E1-E10	/IO/	ENDSTA,ENDYR,GET, GLOBAL,OPENIO, STATE,UNSCNR
I23		Variable I/O unit reference for new unit construction file	/IO/	ENDYR,GLOBAL,G23ACC, OPENIO
I70A,I70B		Variable I/O unit reference for two data group 70 files	/IO/	GLOBAL,OPENIO,UNSCNR
I70CHG		Flag to indicate change to data group 70 (0 = no change)	/G70PRM/	G70ACC,UNSCNR
I70DST		I/O unit reference for disk file to which data group 70 is currently being written (destination file)	/G70PRM/	G70ACC,UNSCNR
I70REC		Data group 70 record in core	/G70PRM/	G70ACC,UNSCNR
I70SRC		I/O unit reference for disk file from which data group 70 is currently being read (source file)	/G70PRM/	G70ACC,UNSCNR

Table C3-6 (contd.)

Variable	Dimensions	Description	Location	Accessed by
I805		Variable I/O unit reference number for unit inventory dump file	/IO/	GLOBAL,OPENIO
Key		Scenario parameter number		GETSCN
LOCMAX		Maximum number of allowed entries in new unit construction schedule (Data Group 23)	/G23PRM/	G23ACC,STATE
LSPART	3,100	LSPART(IRET,J) indicates whether location J in retrofit schedule IRET is available (zero) or not available (nonzero)	/RETROS/	ENDYR,RTROAC,STATE
LSPA23	300	LSPA23(i) indicates whether location i in data group 23 is available (zero) or not available (nonzero)	/G23/	ENDYR,G23ACC,STATE
MAXRTR		Maximum number of entries allowed in any retrofit construction schedule (Data Groups 32, 33, and 34)	/RTROPM/	RTROAC,STATE
MODNAM	2,7	Module names corresponding to IMOD	/CERROR/	ENDSTA,ERROR,G23ACC, IOERR,LENGTH,RTROAC
MTRACE	7	User-specified trace level for each module	/CONTRL/	AUSM,BEGNYR,ENDSTA, ENDYR,GLOBAL
NCOALS		Number of coal types in E6: URGE = 33	/COALS/	BEGNYR,GET,GLOBAL, STATE

Table C3-6 (contd.)

Variable	Dimensions	Description	Location	Accessed by
		EIA = 40		
NCORET		Maximum number of entries in the retrofit schedules that may be held in core (overflow entries are written to disk)	/RTROPM/	ENDYR,RTROAC
NCOR23		Maximum number of entries in data group 23 that are in memory (overflow entries are written to disk)	/G23PRM/	ENDYR,G23ACC
NDPTS	6	Number of projection points in demand series	/DMDINP/	GET
NFYRS	10,7	Column i contains projection years for which data are provided for fuel type i in data group 74 (alternate fuel prices)	/GENERL/	GET,GLOBAL
NGPAR		Number of global scenario parameters	/SCENAR/	GETSCN,GLOBAL,STATE
NGPRST	5,56	State/data group lengths accessed by function LENGTH	/NGPRST/	ENDYR,G23ACC,G70ACC, LENGTH, RTROAC,UNSCNR
NITMS		Number of items to access; if zero, all are accessed		G23ACC,G70ACC,RTROAC
NLENG		Length of a data group		GET,PUT
NNOTES		Number of note lines in file E8		GLOBAL
NOTE	23	Note line from file E8		GLOBAL

Table C3-6 (contd.)

Variable	Dimensions	Description	Location	Accessed by
NPTS	7	Number of projection points provided for each of the seven alternate fuel prices included in data group 74	/GENERL/	GET,GLOBAL,STATE
NPTSDM	6	Number of projection points in demand series	/DMDINP/	GLOBAL,STATE
NRETRO	3	Number of entries currently contained in the three retrofit schedules	/RTROPM/	ENDYR,GET,PUT,RTROAC, SGET,SPUT,STATE
NSCHED		Number of entries currently contained in data group 23, the new unit construction schedule	/G23PRM/	ENDYR,GET,G23ACC,PUT, SGET,SPUT,STATE
NSPAR		Number of state-specific scenario parameters	/SCENAR/	GLOBAL,STATE
NUNITS		Number of units in data group 70	/G70PRM/	BEGNYR,ENDYR,GET,G70ACC, SGET,SPUT,UNSCNR
NUPRBL		Number of units per "block" in data group 70; also maximum number of units from data group 70 that may be held in core	/G70PRM/	G70ACC, UNSCNR
NVALS		Number of items in I/O request		SGET,SPUT
NVCNST		Number of items per entry in data group 23 (new unit construction schedule)	/G23PRM/	ENDYR, G23ACC
NVRTRO		Number of items per entry in data		

Table C3-6 (contd.)

Variable	Dimensions	Description	Location	Accessed by
		groups 32, 33, and 34 (retrofit schedules)	/RTROPM/	ENDYR, RTROAC
NVR5A		Number of items per entry in file E5A.	/G70PRM/	UNSCNR
NVR5H		Number of items per entry in file E5; also number of items in data group 70 (unit inventory)	/G70PRM/	BEGNYR,G70ACC, UNCHNG,UNSCNR
N70REC		Number of records on disk files associated with unit inventory	/G70PRM/	G70ACC, UNSCNR
PARAM	200	Scenario parameters	/SCENAR/	BEGNYR,GET,GETSCN, GLOBAL,STATE
PRICE	10,7	Projected prices for noncoal fuels	/GENERL/	GET,STATE
RNSPS	23	User-specified revisions to RNSPS and corresponing effective years; read from E8, the scenario file	/CTCOM/	BEGNYR, STATE
RP700	44	Coal data parameters		GLOBAL
RTDFLT	12	Default values for a new entry in one of the retrofit schedules	/RETROS/	RTROAC
RTROS	3,12,10	Holds retrofit data in memory	/RETROS/	ENDYR,RTROAC
SO2CAT	11,2	Coal sulfur categories URGE/EIA		BEGNYR
SO21,SO22		Sulfur content of first and second coals		BEGNYR
TIME	7	Timing estimate for each module (optional; based on local installations)	/CONTRL/	AUSM, ENDSTA,ERROR

Table C3-6 (contd.)

Variable	Dimensions	Description	Location	Accessed by
TOTYR		Number of years in coal data projection series	/COAL/	BEGNYR,ENDSTA,GET, GLOBAL,STATE
TRNPOW	30,2	Quantities and costs of net power transfers	/DMDINP/	GET,STATE
UNDFLT	72	Default values for a new entry in data group 70	/UNINVY/	G70ACC
VLIST	Variable	Values passed in calls to URGE I/O routines		GET,G23ACC,G70ACC,PUT, RTROAC,SGET,SPUT
YRS17		Number of projection years in data group 17	/DMDINP/	GET,STATE

REFERENCES

1. James J. Stukel. "**Advanced Utility Simulation Model, Analytical Documentation, State Level Model (Version 1.0).**" U.S. Environmental Protection Agency. EPA-600/8-88-071a. January 1989.

2. Caroline J. Badger and Howard Ojalvo. "**Advanced Utility Simulation Model, Documentation of System Design, State Level Model (Version 1.0).**" U.S. Environmental Protection Agency. EPA-600/8-88-071c (NTIS PB89-101208). August 1988.

C4. THE DEMAND MODULE

by
M. Czerwinski, T. Mount, A. Schwartz, T. Motyka and D. Turck

Universities Research Group on Energy
Cornell University

4.1 Overview

The demand module of the Advanced Utility Simulation Module (AUSM) determines the following information for other modules:

1. The level of generation and peak load demanded in the current year, net of interstate transfers (for the dispatching module),
2. Total revenue and the net cost of transfers (for the financial module), and
3. Projected levels of generation and peak load, both net of interstate transfers (for the capacity planning module).[1]

For the demand module to perform it tasks, information from the financial module is first used to set rates for electricity (except in the first year of a simulation, because demand is the first module called by the control program). Figure C4-1 is a schematic diagram of the major components of the demand module; the relationship of the demand module to the other AUSM modules is also shown. Figure C4-2 shows the control data flow.

This chapter describes the four major components of the demand module: rate schedule updating, demand equations, utility load characteristics and demand projections. Three different modes of operation are available with the demand module: normal, or endogenous demand (i.e., determined by the demand equations), exogenous demand (i.e., specified by the user) and exogenous demand with annual recursiveness (i.e., responsive to changes in generation costs from an exogenous base scenario). References will be made

---

[1] The demand module also determines levels of demand for electricity and other fuels. This information will be used in the national-level AUSM by the energy and employment impacts module [1], which operates only at the national level.

Figure C4-1
SCHEMATIC REPRESENTATION OF THE DEMAND MODULE

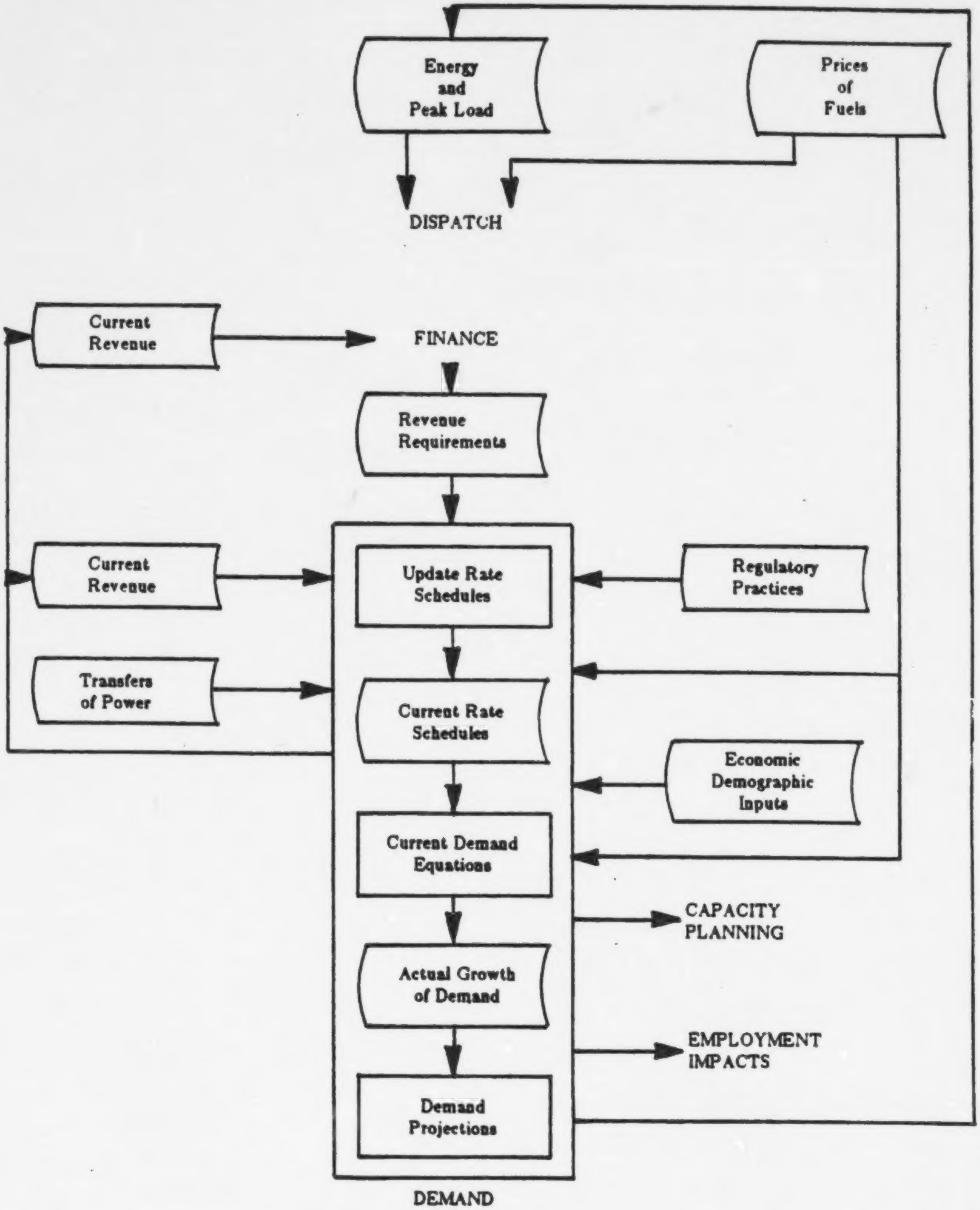
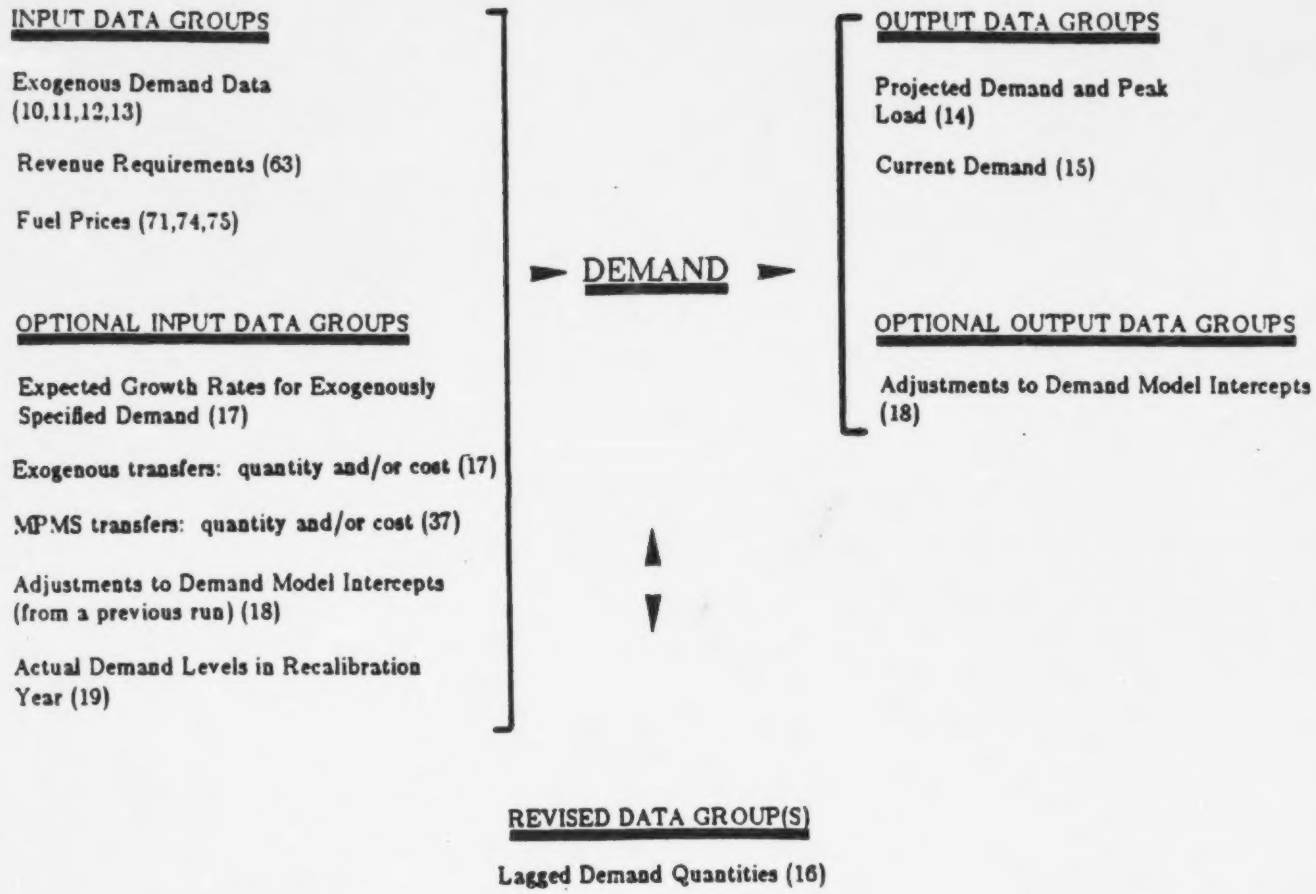


Figure C4-2

DATA FLOW OF THE DEMAND MODULE



INPUT DATA GROUPS

Exogenous Demand Data (10,11,12,13)

Revenue Requirements (63)

Fuel Prices (71,74,75)

OPTIONAL INPUT DATA GROUPS

Expected Growth Rates for Exogenously Specified Demand (17)

Exogenous transfers: quantity and/or cost (17)

MPMS transfers: quantity and/or cost (37)

Adjustments to Demand Model Intercepts (from a previous run) (18)

Actual Demand Levels in Recalibration Year (19)

DEMAND

OUTPUT DATA GROUPS

Projected Demand and Peak Load (14)

Current Demand (15)

OPTIONAL OUTPUT DATA GROUPS

Adjustments to Demand Model Intercepts (18)

REVISED DATA GROUP(S)

Lagged Demand Quantities (16)

throughout to the analytical documentation of the demand module (Chapter 2 of Reference 2). Section 2.1 of that documentation presents the underlying rationale for the module's design.

4.2 Central Algorithms and Basic Assumptions

4.2.1 Update Rate Schedules

New aggregate rates for electricity by demand sector are determined as a two-part tariff. The implication is that a fixed customer charge is made together with a fixed marginal price for each kilowatt hour. This strategy provides information for the demand equations while allowing flexibility for policy analyses. The method for updating rate schedules that is implemented as described below approximates standard rate-making practices. New rates for electricity are calculated as adjusted increments to the previous years' average fuel and nonfuel costs using information from the financial module about revenue required (RQ1) to cover all costs, and the percentages of revenue required for different fuel and nonfuel costs. Adjustment factors, reflecting regulatory delays for passing on higher fuel and nonfuel costs, modify these increments to determine actual adjustments to rates (see Reference 2, Section 2.2.1).

The sectoral marginal prices and customer charges are represented by

PRICIN(2,NS), where $NS = 1,3$ represents marginal prices in \$/MMBtu and

PRICIN(3,NS), where $NS = 1,3$ represents customer charges in \$/capita/year

($NS = 1$ for the residential sector, 2 for the commercial sector, and 3 for the industrial sector.) For the increment to the fuel component of costs, the cost of fuels used for generation at the previous year's fuel prices (FCOLD) is determined from the product of revenue required (RQ1) and the sum of the revenue requirements for fuels (RVQPCT). The cost of fuels used for generation at current prices (FCNEW) is determined from the product of revenue required and the sum of the revenue requirements for fuels weighted by the ratio of current prices to the previous year's prices. The ratio of these costs is then used to escalate the previous year's average fuel costs (AVFC). The fuel cost increment for all sectors, in dollars per million Btu, is

$$FPESC = (AVFC/3.412 * ((FCNEW/FCOLD) - 1.0).$$

The marginal price in all sectors is revised to equal the previous year's marginal price plus the adjusted fuel price increment:

$$PRICIN(2,NS) = PRICIN(2,NS) + ADJF * FPESC$$

where ADJF ($\leq$ 1) is the adjustment factor measuring regulatory delays.

The nonfuel component of costs is passed on in proportion to the revenue received for nonfuel costs in each sector; typically, both the marginal price and the customer charge are affected. RN is the adjusted nonfuel escalation factor, which is the ratio of the allowed increase in the nonfuel component of average price in the current year to the previous year's average nonfuel cost (AVNFC):

$$RN = ADJNF * (RQ1 - P5(17))/OQR(5)/AVNFC$$

where (RQ1 - P5(17)) is the difference between the previous year's total revenue requirements (RQ1) and actual revenue received (P5(17)), and ADJNF ($\leq$ 1) is the regulatory adjustment factor. This product is divided by the previous year's total sales (OQR(5)) to give the allowed nonfuel increment per kilowatt hour. Hence, RN gives the allowed proportional change for the nonfuel components of rates, which may be positive, negative, or zero.

The average cost of fuel (AVFC) can be subtracted from the average price paid in each sector to give the average nonfuel cost per kilowatt hour (SNFC(NS)). This cost is covered by the nonfuel component of the marginal price and the customer charge. The nonfuel component of the marginal price for a given sector can be written in terms of the average and marginal prices in dollars per million Btu (APES(NS) and PRICIN(2,NS), respectively), as follows:

$$\begin{aligned} RNN &= SNFC(NS)/3.412 + PRICIN(2,NS) - APES(NS) \\ &= PRICIN(2,NS) - AVFC/3.412 \end{aligned}$$

This quantity may be negative for some observations, implying that the marginal price does not cover average fuel costs. In general, however, when RNN is greater than zero, the nonfuel components of the marginal price and the customer charge are changed by the nonfuel factor (RN). The marginal price and customer charge are modified as follows:

$$PRICIN(2,NS) = PRICIN(2,NS) + RN * RNN$$

$$PRICIN(3,NS) = PRICIN(3,NS) * (1 + RN).$$

These modifications are made whether RN is positive, negative, or zero.

For the unusual cases in which marginal prices are lower than average fuel costs (RNN $<$ 0), an increase in the nonfuel component (RN $>$ 0) is passed on through a higher marginal price, leaving the customer charge unchanged. In contrast, a decrease (RN $<$ 0) is passed on by reducing the customer charge, leaving marginal prices unchanged. This is done to ensure that the nonfuel increments to the marginal price and the customer charge do not have opposite signs. These modifications can be summarized as follows: If RNN $\leq$ 0 and RN $>$ 0

$$PRICIN(2,NS) = PRICIN(2,NS) + RN * SNFC(NS)/3.412$$

PRICIN(3,NS) is unchanged.

If RNN $\leq$ 0 and RN $\leq$ 0

PRICIN(2,NS) is unchanged (except for the fuel component)

$$PRICIN(3,NS) = PRICIN(3,NS) + RN * Q1S(NS) * SNFC(NS)/3.412$$

where Q1S(NS) is the sectoral quantity of electricity used per capita.

4.2.2 Demand Equations

The demand equations provide predictions of the quantities of electricity and major primary fuels demanded in each sector for specified prices of electricity and of primary fuels and other inputs, such as income and employment. For the residential sector the demand levels for electricity, natural gas, oil (light) and oil (motor) are determined. In the commercial sector, the quantities are electricity, natural gas, oil (light) and oil (heavy); and in the industrial sector, they are electricity, natural gas, oil (light), oil (heavy) and coal. For the transportation sector, only electricity demand is determined (this quantity is zero in most states, and very small relative to the other sectors in the remaining states).

Sectoral per capita quantities (in million Btu) by fuel type within each sector[2] are determined using a dynamic linear logit form from expenditure shares (WT(I,NS)) based on functions (F(I) within sectors) of explanatory variables (V(J,I,NS), where J denotes variable number) such as prices, the associated coefficients (COEF(J,I,NS)), and lagged quantity ratios.[3] It should be noted that the coefficients in the estimated models are weighted so that constraints derived from economic theory can be incorporated. In order to simplify the expressions, the values of the estimated coefficients and the weights are combined to form COEF(J,I,NS).

For each state and fuel type within each sector, the F(I) are initialized to the estimated intercept (F(I) = AINTER(I,NS)). If the user specifies that demand should duplicate an exogenous path that has been defined in an earlier run, the intercepts are modified by weights for each fuel (W(f), where f = 1 for electricity, 2 for natural gas, 3 for oil, and 4 for coal). In the commercial and industrial sectors, the form is:

$$F(I) = F(I) + ALOG(W(f)),$$

while in the residential sector the form is:

$$F(I) = F(I) + (ALOG(W(f)) - ALOG(W(5))),$$

where $W(5)$ is an additional weight needed to ensure that the sum of expenditures equals income. These weights are set to 1.0 for normal demand, implying no adjustment to the intercept.

---

[2] Q1S(I,NS), where i denotes fuel type and equation number, and NS = 1 for the residential sector, 2 for the commercial sector, and 3 for the industrial sector.

[3] See Section 2.2.2 of Reference 2 for a detailed discussion of the structure of the model and for details of the estimated models and coefficients.

Each F(I) is then iterated through the explanatory variables (J) to give:

$$F(I) = F(I) + \sum_{J} COEF(J,I,NS) * V(J,I,NS)$$

where V is either of the form ALOG(P1S(J,NS)) (i.e., the log of prices and other explanatory variables), or ALOG(Q1S(I,NS)/Q1S(N,NS)) (i.e., the log of lagged quantity ratios).[4]

The computed expenditure shares are always nonnegative and sum to one. The first (N - 1) shares WT(I,NS) are initialized at 0.0 and the Nth share, WT(N,NS), is initialized at 1.0. The shares are then computed in the following sequence:

$$WT(N,NS) = WT(N,NS) + \sum_{I} (EXP(F(I)))$$

$$WT(I,NS) = EXP(F(I))/WT(N,NS)$$

$$WT(N,NS) = 1.0/WT(N,NS).$$

The quantities of fuel demanded can be determined directly from the estimated shares (WT(I,NS)) using income in the residential sector and employment levels in the commercial and industrial sectors, since these variables are inputs into the demand module.

Residential sector (N = 1):

$$Q1S(I,1) = WT(I,1) * P1S(6,1)/P1S(I,1)$$

$$\text{for } I = 1,2,3,4$$

where Q1S(I,1) is the quantity of fuel I per capita, P1S(6,1) is income per capita, and P1S(I,1) is the price of fuel I.

Since employment rather than total cost is an input in the commercial and industrial sectors (NS = 2 and 3), the quantities can be determined directly from the functions F(I) as follows:

---

[4] See Table C4-4 for sectoral explanatory variables and Tables C4-1 through C4-3 for the relationship between input and sectoral demand variables.

$$Q1S(INS) = EXP(F(I)) \ast Q1S(N,NS) \ast P1S(N,NS)/P1S(I,NS)$$

where $P1S(N,NS)$ and $Q1S(N,NS)$ are the price and per capita quantity for labor, respectively, with N = 5 in the commercial sector and N = 6 in the industrial sector.

In the current version of the model, the quantity of electricity in the transportation sector is determined as a fixed fraction of the commercial sector use:

$$Q1S(1,4) = STRNQR \ast Q1S(1,2)$$

where *STRNQR* is the observed ratio of sales in the transportation sector to sales in the commercial sector in 1980. Revenues in the transportation sector are similarly determined using *STRNRR* (the observed ratio of revenues in the transportation sector to revenues in the commercial sector in 1980).

In addition, for electricity, per capita sectoral revenues (*RV1S*) and average sectoral prices (*APES*) are calculated as follows (for NS = 1, 2, and 3):

$$RV1S(1,NS) = PRICIN(3,NS) + (Q1S(1,NS) \ast P1S(1,NS)$$

$$APES(NS) = P1S(i,NS) + (PRICIN(3,NS)/Q1S(1,NS)).$$

4.2.3 Load Characteristics

For electricity, total per capita sales in million Btu (Q1S(1,5)) and revenues in million dollars per capita (RV1S(1,5)) are calculated as the sum across the four sectors. The overall average price of electricity (APE) is computed from these totals, and the total sale of electricity in billion kilowatt hours (Q1.OQR(6)) is calculated by multiplying total per capita sales by the current size of the population (PRICIN(14,1)) and converting the units to kilowatt hours.

Required generation (RG) is then computed by modifying total sales to account for distribution and transmission losses using a national average loss factor (LOSSF $\geq$ 1):

$$RG = Q1 \ast LOSSF.$$

The treatment of transfers of power (Q3) and the cost of transfers (RV3) depend upon the value of GETSCN(105), as follows

If GETSCN(105) equals 0, transfers are treated as a constant, determined from the observed ratio of actual generation to required generation in 1980 (TRANF):

$$Q3 = RG * (1 - TRANF).$$

The cost is determined using the industrial marginal price of electricity:

$$RV3 = Q3 * P1S(1,3).$$

If GETSCN(105) equals 1, quantity and cost data are input from MPMS via data group 37.

If GETSCN(105) equals 2, quantity and cost data are input exogenously via data group 17.

If GETSCN(105) equals 3, quantities are input exogenously via data group 17 but costs are determined internally using the industrial marginal price of electricity.

State-level generation (SG) is determined as required generation less transfers (SG = RG - Q3).

Peak load (Q2(1)) in megawatts is calculated from state-level generation using a specified load factor (P2(5)). NERC regional load factors are used for all states in the respective regions. (See Reference 1, Section 2.2.3.)

4.2.4 Demand Projections

Projected generation net of transfers (PQ1(I)) is calculated for the next 15 years using an expected growth rate (EXPGRP) applied to the previous year's required generation (RGOLD) and then adjusted for transfers of power:

$$PQ1(I) = (RGOLD * (1 - EXPGRP/100.) ** J) - Q3$$

where J = I + 1 and I = 1,15.

Peak load, net of transfers (PQ2(I)), is then calculated from PQ1(I) using the specified load factor for the current year. One option permits users to keep projected sales and load on exactly the same exogenous growth path as current demand. In this case, specified future load factors, rather than the current load factor, are used to convert projected sales to projected peak load.

The expected growth rate (EXPGRP) is a four-year moving average of actual growth rates of sales in the four preceding years using coefficients, GRB and GRC, from a model of actual utility forecasting practices. Regional intercepts, GRA, are specified but these are reduced to 0 over the first five years of a simulation run.[5] The current year's actual growth rate of sales (EXPGRA) is calculated and saved for use in the following years.

4.2.5 Modes of Operation

The demand module operates in three different modes, controlled by scenario parameter (EXOGDS) as follows (see Figure C4-5):

Parameter Value[6]	*Mode of Operation*
0	Normal, or endogenous demand (i.e., determined by the demand equations).
1	Exogenous demand (i.e., specified by the user).
2	Exogenous demand with annual recursiveness (i.e., responsive to changes in generation costs from a base scenario).

In order to implement exogenous demand with annual recursiveness (EXOGDS = 2), it is necessary first to calculate a set of fuel-specific weights (W's) corresponding to a given set of exogenous (total) demand specifications (EXOGDS = 1). If these weights are used as adjustments to the demand model intercepts (see above, Section 4.4.2) with the same inputs as before, then the same exogenous demand level is determined from the demand equations. In subsequent runs with different inputs (e.g., cost of controlling emissions), demand will respond to changes in generation costs.

---

[5] See Reference 2, Section 2.2.4, for a discussion of the estimated model and coefficients.

[6] An additional option, when EXOGDS = 3, also forces the outputs for the planning module to be specified exogenously. In other words, there is no error in the forecasting of future demand for planning purposes. This option operates in the same fashion as EXOGDS = 1 except that W's (adjustments to demand model intercepts) are not saved.

The demand module accepts levels of total sales of electricity (and, optionally, natural gas, oils, and coal), much as it accepts levels of prices and other external inputs. Thus, since the user may specify exogenous demand (EXOGDS = 1) in terms of expected growth rates for up to five specified time periods, conversion to levels is performed, by subroutine GETQ, in order to make this scenario information available to the demand module. The scenario parameter EXOGDQ controls whether specification of exogenous demand is for one (electricity) or four fuel types. In this case, for each simulation year, a set of fuel specific weights (W(I)) must be determined as the ratio of the total exogenous demand (XQ(I), where I = 1, 2, 3, 4 for the four fuel types) to the total endogenous demand (TQ(I)) and the associated sectoral "extra" fuel costs (ECOST(NS), where NS = 1, 2 or 3). Expenditure shares (WT(I,NS)) and sectoral per capita quantities (Q1S(I,NS)) can then be recalculated using the W(I).

There is another option which may be useful with the first two modes of operation to recalibrate the levels of demand to correspond to up-to-date information. To provide for this type of accuracy, a recalibration procedure can be selected for one (electricity) or four fuel types for a specified year (controlled respectively by scenario parameters EXOGDR and IYRCAL). This is not an alternative to specifying demand exogenously but merely an extension to incorporate current information about actual sales (e.g., for 1982). After 1982, demand can be predicted in the usual way or specified exogenously by growth rates.

4.3 Data Handling

4.3.1 Input Data

Input data for the demand module consist of the following six types together with various optional scenario characteristics:

1. Exogenous national demand data (invariant), including demand model coefficients, projection model coefficients, and a loss factor, are accessed only on the first call to the demand module (from data group 10)[7] and stored in COMMON/DNAT/.

---

[7] See Reference 2 for a more detailed description of all the data groups and Tables C4-2 and C4-3 where variables P0, P1, and P2 are labeled.

2. Exogenous national demand data (varying by year), including indices for the prices of appliances, cars, and nonfuel expenditures, are accessed once for each year of the simulation run (i.e., a state change is immaterial). This information, from data group 11, is stored in COMMON/DNATYR/.

3. Exogenous state demand data (invariant), including demand model intercepts, demand model variable differences, projection model intercepts, transfers, and revenue adjustment factors, are accessed once for each state in the simulation run (from data group 12). Those data are stored in COMMON/DST/. In the first year of the simulation run for each state the variable differences are calculated using initial demand model values from data group 12. These values are then replaced in data group 12 so that all subsequent years' run for the state may access the differences.

4. Exogenous state demand data (varying by year) are accessed for every iteration of the simulation run and held in blank common (which will be overwritten by subsequent modules). These data include:

- Alternate fuel prices (from data group 74)

- Coal price (from data group 71 and 75 via subroutine GETCOL)

- Exogenous economic and demographic variables, including total personal income, population, total and manufacturing employment, and (regional) load factors (from data group 13)

- Demand module working arrays, including lagged sectoral quantities, prices, and economic and demographic variables (from data group 16)

- Revenue requirements percentages and total revenue requirements from the financial module (via data group 63)

- Adjustments to demand model intercepts (from data group 18); for optional scenario specification of exogenous demand with annual recursiveness.

- Transfers of power and/or costs of transfers; for optional scenario specification (from data group 37 for MPMS data; from data group 17 for exogenous user specification).

5. Expected growth rates for total sales of electricity, or of electricity, natural gas, oils, and coal are optional data, used to specify scenarios for exogenous demand. These growth rates are from data group 17.

6. Actual levels of total sales of electricity, or of electricity, natural gas, oils, and coal are also optional scenario specifications. These levels (from data group 19) are used to recalibrate demand.

4.3.2 Output Data

Output data for every state-year include trace output (on unit 11), report output (on unit 10), and output for other modules, as follows:

1. Energy and peak load (projected, net of transfers), for the capacity planning module (via data group 14).

2. Generation and peak load (current, net of transfers), for the dispatching module (to data group 15).

3. Total revenue received, net of transfers, and net cost of transfers, for the financial module (to data group 15).

4. Demand model working arrays, for use by the module in subsequent iterations of the simulation run (to data group 16).

5. Adjustments to demand model intercepts (to data group 18). These adjustments are calculated when running an exogenous demand scenario and are for use in subsequent (policy) runs where exogenous demand with annual recursiveness is specified.

4.4 Subprogram Descriptions

Subsections 4.4.1, 4.4.2, and 4.4.3 summarize, respectively, the three subroutines in the demand module. DEMAND is the main routine in the module, PRERR is a warning message indicator routine for demand equation fuel prices, and GETQ is a subroutine that determines levels of total sales by fuel type for exogenous or recalibrated demand.

4.4.1 Subroutine DEMAND

Name: DEMAND

Called by: CONTROL

Calls: Control routines GET, GETSCN, ERROR, PUT; system routines ALOG, EXP, IFIX; subroutines PRERR, GETQ, GETCOL.

Arguments: ISTATE, IYEAR, ITRACE

Tasks: The program has three main sections:

Update rate schedules, which calculates sectoral marginal prices of electricity and customer charges.

The demand model itself, which calculates generation and peak load demanded in the current year, net of interstate transfers, for the dispatching module; total revenues and net cost of interstate transfers, for the financial module; and levels of demand for electricity and other fuels for the energy and employment impacts module. Variables include:

Q1	Generation demanded in current year, net of transfers, in billion KWh
Q2(1)	Peak load demanded in current year, net of transfers, in MW
RV1	Total revenues received in current year, in million dollars
RV3	Net cost of transfers, in current year, in million dollars
Q1S	Sectoral levels of demand for other fuels, in current year, in millions of Btu per capita

Projections which calculate the projected level of generation, net of interstate transfers, and the projected peak load, net of interstate transfers, for the capacity planning module. Variables include:

PQ1	Projected generation for 15 years, in billion KWh
PQ2	Projected peak load for 15 years, in MW

Method: For update rate schedules, new sectoral marginal prices and customer charges are calculated taking into account fuel and regulatory adjustment factors and the lagged effect on revenue requirements.

For the demand model, a linear logit model of demand yields sectoral per capita levels of the demand for electricity and other fuels, and resulting revenues; totals for electricity yield revenues, net cost of transfers, and demand. Demand, when modified by loss and transfer factors, yields generation, net of transfers. This is modified by a state load factor giving peak load, net of transfers.

For projections, levels of generation and peak load, net of transfers, are forecast (using lagged generation and current expected growth of total sales) for 1 to 15 years ahead. (The current expected growth of total sales is based on the actual growth rate for the four preceding years.)

Error Handling: In update rate schedules, a terminal error (via ERROR) will occur if total revenues are insufficient to cover fuel costs.

Two types of warning messages may be written (via PRERR) and reported to the control program (via ERROR). The first will occur if sectoral fuel prices are less than $1 per MMBtu; the second if internal sectoral fuel price relationships are not maintained.

Notes: Depending upon scenario specification of the parameter EXOGDS (exogenous demand switch), the demand module will operate in one of three modes as follows: 0 = normal or endogenous demand; 1 = exogenous demand; 2 = exogenous demand with annual recursiveness. If EXOGDS = 3, operation is as if EXOGDS = 1 but outputs for planning are also specified exogenously and adjustments to intercepts are not saved.

The scenario parameter EXOGDQ controls fuel types for which expected growth rates for total sales are supplied exogenously; EXOGDR performs in a similar function for the specification of levels to be used in demand recalibration. IYRCAL is a scenario parameter indicating the recalibration year.

4.4.2 Subroutine PRERR

Name: PRERR

Called by: DEMAND

Calls: Control routine ERROR

Arguments: ISTATE, IYEAR, ITYP, I, J

Task: Prints warning messages for demand model fuel prices.

Method: If ITYP = 1, prints price reset to 1.0 message.
If ITYP = 2, prints reset to another fuel price.

For residential sector (J = 1):
Fuel type = I = 2 = natural gas or
3 = oil, light or
4 = oil, motor.

For commercial sector (J = 2):
Fuel type = I = 2 = natural gas or
3 = oil, light, or
4 = oil, heavy.

For industrial sector (J = 3):
Fuel type = I = 2 = natural gas or
3 = oil, light, or
4 = oil, heavy, or
5 = coal.

4.4.3 Subroutine GETQ

Name: GETQ

Called by: DEMAND

Calls: Control routines GET, GETSCN, PROJ1

Arguments: IYEAR, ISTATE, XQ

Task: Returns level of total sales of electricity in billion KWH (and, optionally, natural gas, oils and coal) for exogenous demand or recalibration. Variables include:

XQ	Level of total sales of electricity, in billion KWh (and, optionally, natural gas, oils and coal).
EXOGDQ	Exogenous demand quantities switch (scenario parameter).

EXOGDR	Demand recalibration switch (scenario parameter).
IYRCAL	Recalibration year (scenario parameter).

Method: For exogenous demand, growth rates are applied to the level in the previous year. For recalibration, interpolation is performed for IYEAR between the first year of simulation run and the calibration year.

4.5 Subprogram Flowcharts

This section contains flowcharts for subroutines DEMAND and GETQ (Figures C4-3 and C4-4, respectively). Figure C4-5 depicts the scenario/module operation of exogenous demand and recalibration of demand.

Several vectors and/or arrays are used to specify the demand equations. This is because inputs come from a variety of data groups, units are usually different on input than in use, calibration of inputs is performed, and the sectoral ordering of variables to correspond with model coefficients must be ensured. Tables C4-1 through C4-4 are included here in order to summarize these relationships.

4.6 Demand Module Variables

Table C4-5 presents a description of each variable used in DEMAND. Table C4-6 provides more detailed information about these same variables. Descriptions of the variables used in subroutine PRERR appear in Table C4-7; more detailed information is in Table C4-8. Tables C4-9 and C4-10 give the corresponding information for subroutine GETQ.

Figure C4-3
SUBROUTINE DEMAND FLOWCHART

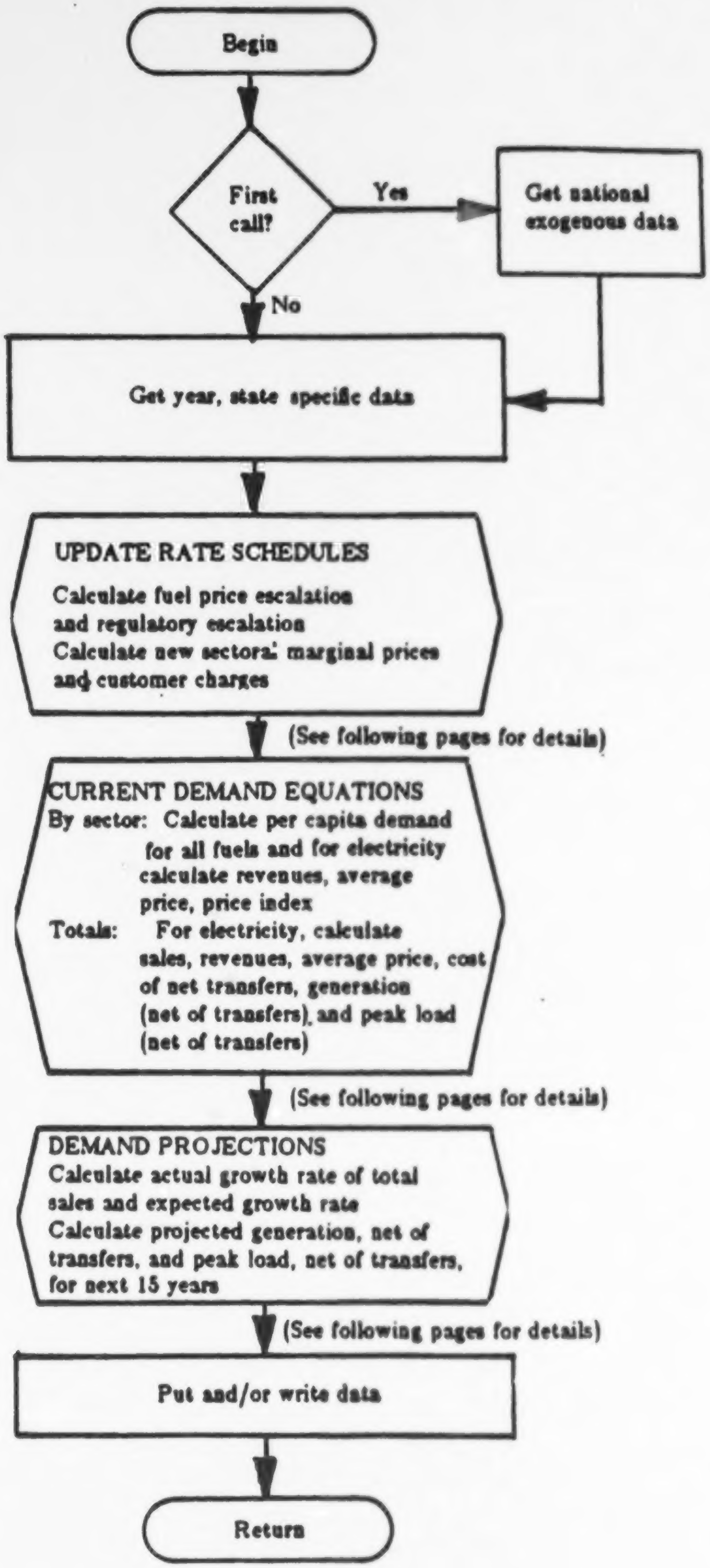
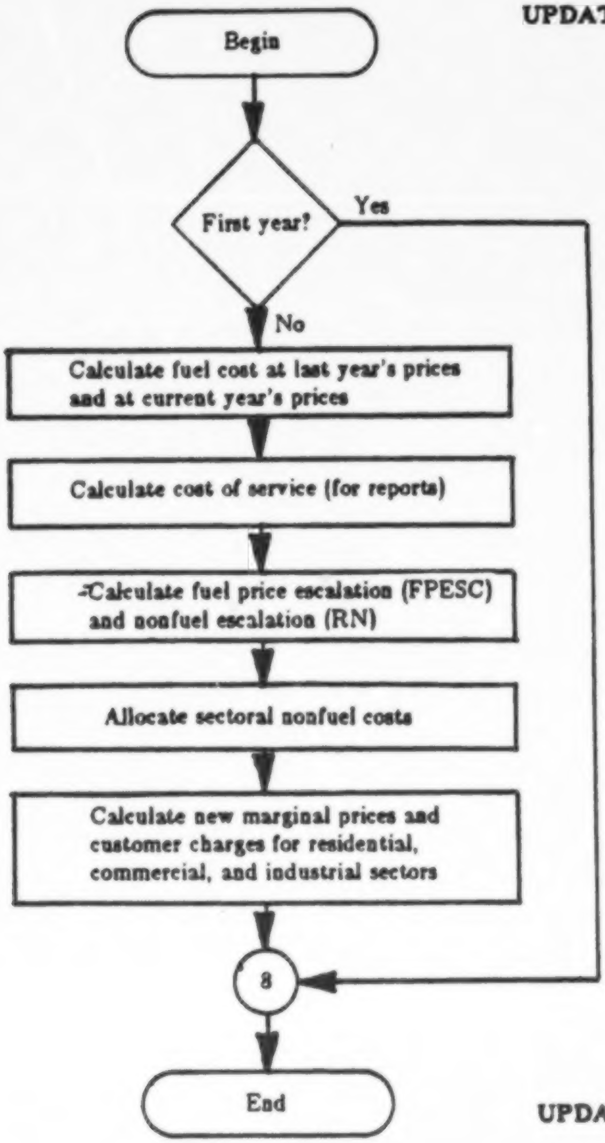

Begin
First call?
Yes
Get national exogenous data
No
Get year, state specific data
UPDATE RATE SCHEDULES
Calculate fuel price escalation and regulatory escalation
Calculate new sectoral marginal prices and customer charges
(See following pages for details)
CURRENT DEMAND EQUATIONS
By sector: Calculate per capita demand for all fuels and for electricity calculate revenues, average price, price index
Totals: For electricity, calculate sales, revenues, average price, cost of net transfers, generation (net of transfers), and peak load (net of transfers)
(See following pages for details)
DEMAND PROJECTIONS
Calculate actual growth rate of total sales and expected growth rate
Calculate projected generation, net of transfers, and peak load, net of transfers, for next 15 years
(See following pages for details)
Put and/or write data
Return

Figure C4-3 (contd.)

UPDATE RATE SCHEDULES


Begin
First year?
Yes
No
Calculate fuel cost at last year's prices and at current year's prices
Calculate cost of service (for reports)
Calculate fuel price escalation (FPESC) and nonfuel escalation (RN)
Allocate sectoral nonfuel costs
Calculate new marginal prices and customer charges for residential, commercial, and industrial sectors
8
End

UPDATE RATE SCHEDULES

Figure C4-3 (contd.)

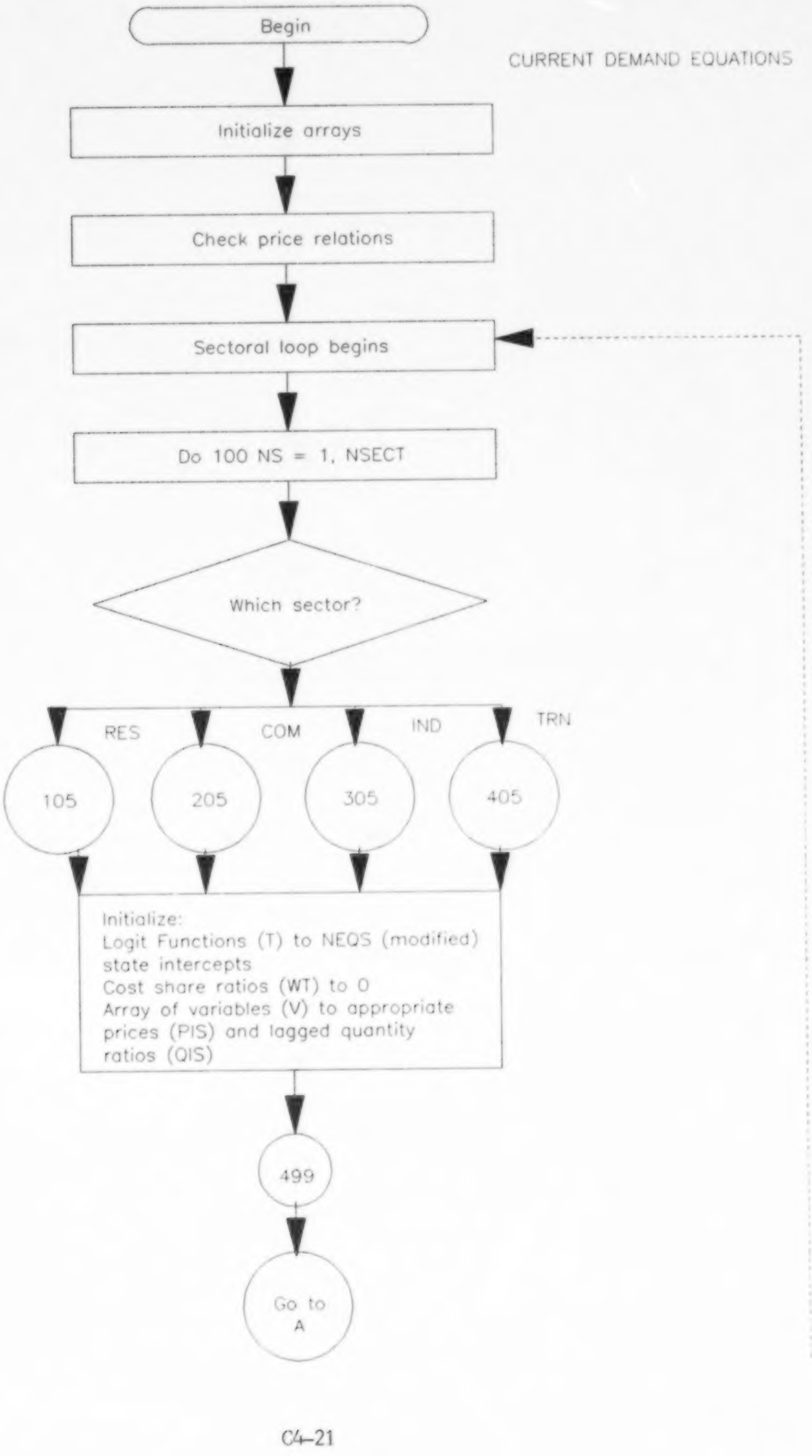


Figure C4-3 (contd.)

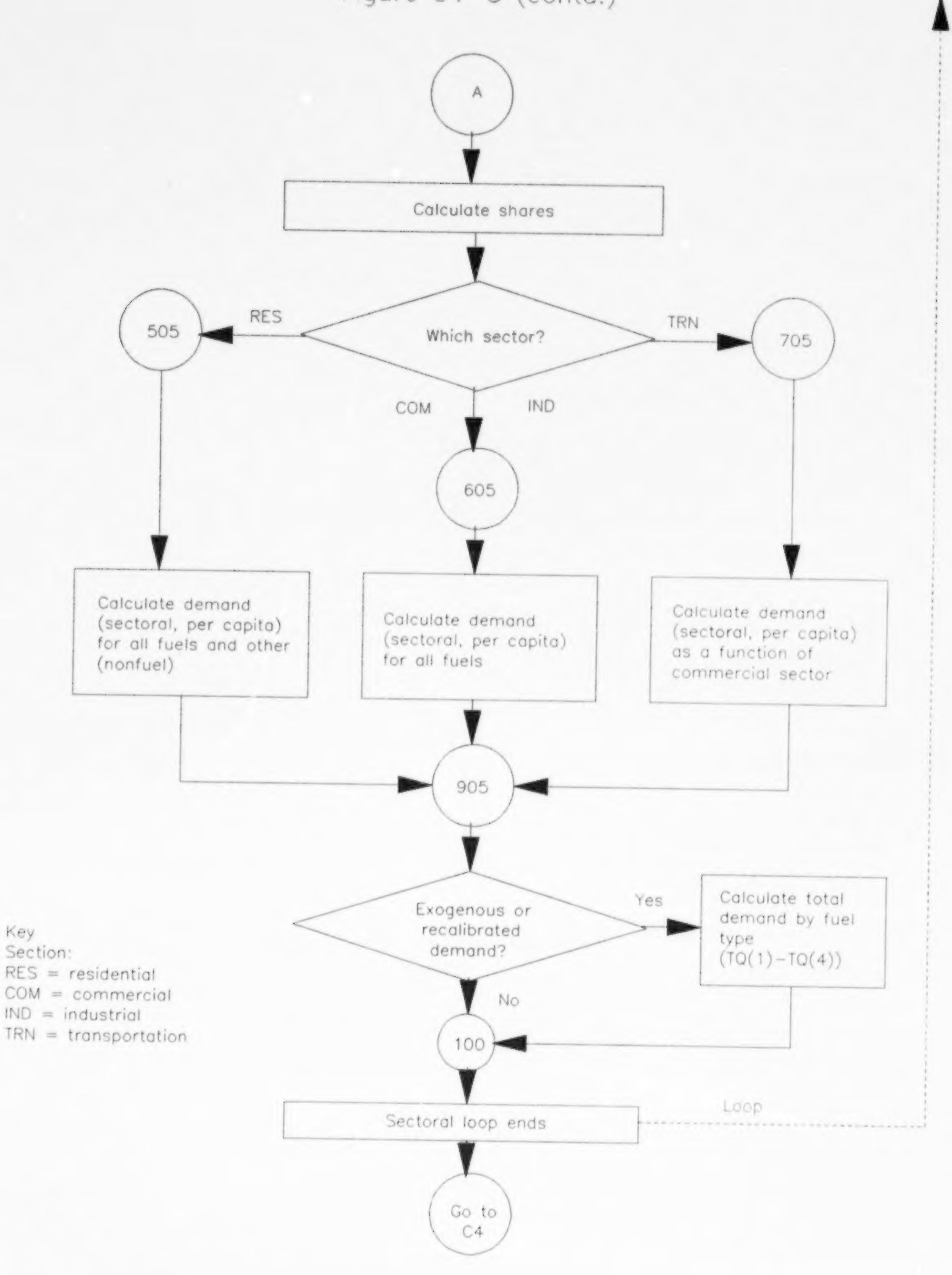
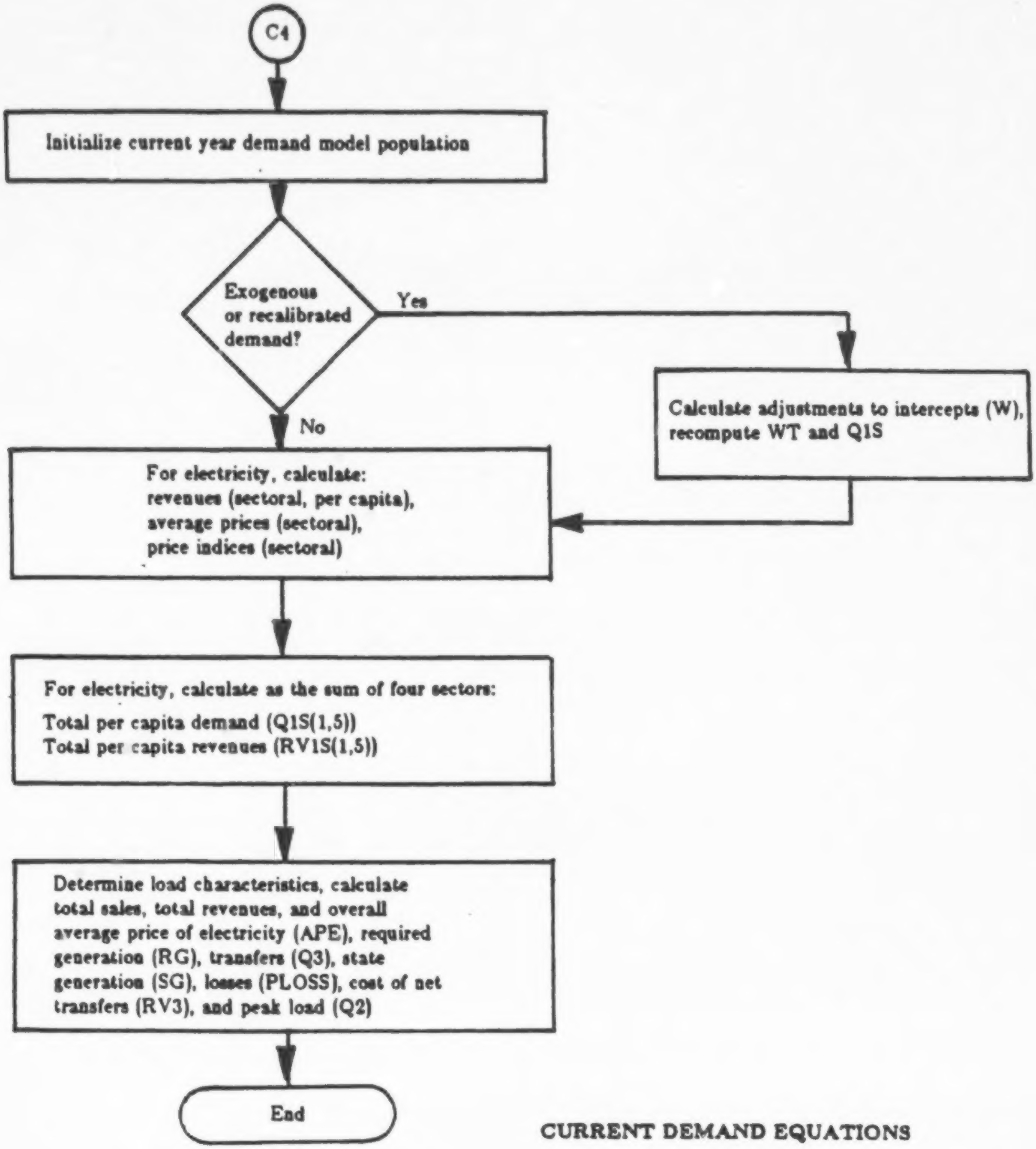

A
Calculate shares
Which sector?
RES
505
TRN
705
COM
IND
605
Calculate demand (sectoral, per capita) for all fuels and other (nonfuel)
Calculate demand (sectoral, per capita) for all fuels
Calculate demand (sectoral, per capita) as a function of commercial sector
905
Exogenous or recalibrated demand?
Yes
Calculate total demand by fuel type (TQ(1)-TQ(4))
No
100
Sectoral loop ends
Loop
Go to C4
Key
Section:
RES = residential
COM = commercial
IND = industrial
TRN = transportation

Figure C4-3 (contd.)


C4
Initialize current year demand model population
Exogenous or recalibrated demand?
Yes
No
Calculate adjustments to intercepts (W), recompute WT and Q1S
For electricity, calculate: revenues (sectoral, per capita), average prices (sectoral), price indices (sectoral)
For electricity, calculate as the sum of four sectors: Total per capita demand (Q1S(1,5)) Total per capita revenues (RV1S(1,5))
Determine load characteristics, calculate total sales, total revenues, and overall average price of electricity (APE), required generation (RG), transfers (Q3), state generation (SG), losses (PLOSS), cost of net transfers (RV3), and peak load (Q2)
End

CURRENT DEMAND EQUATIONS

Figure C4–3 (contd.)

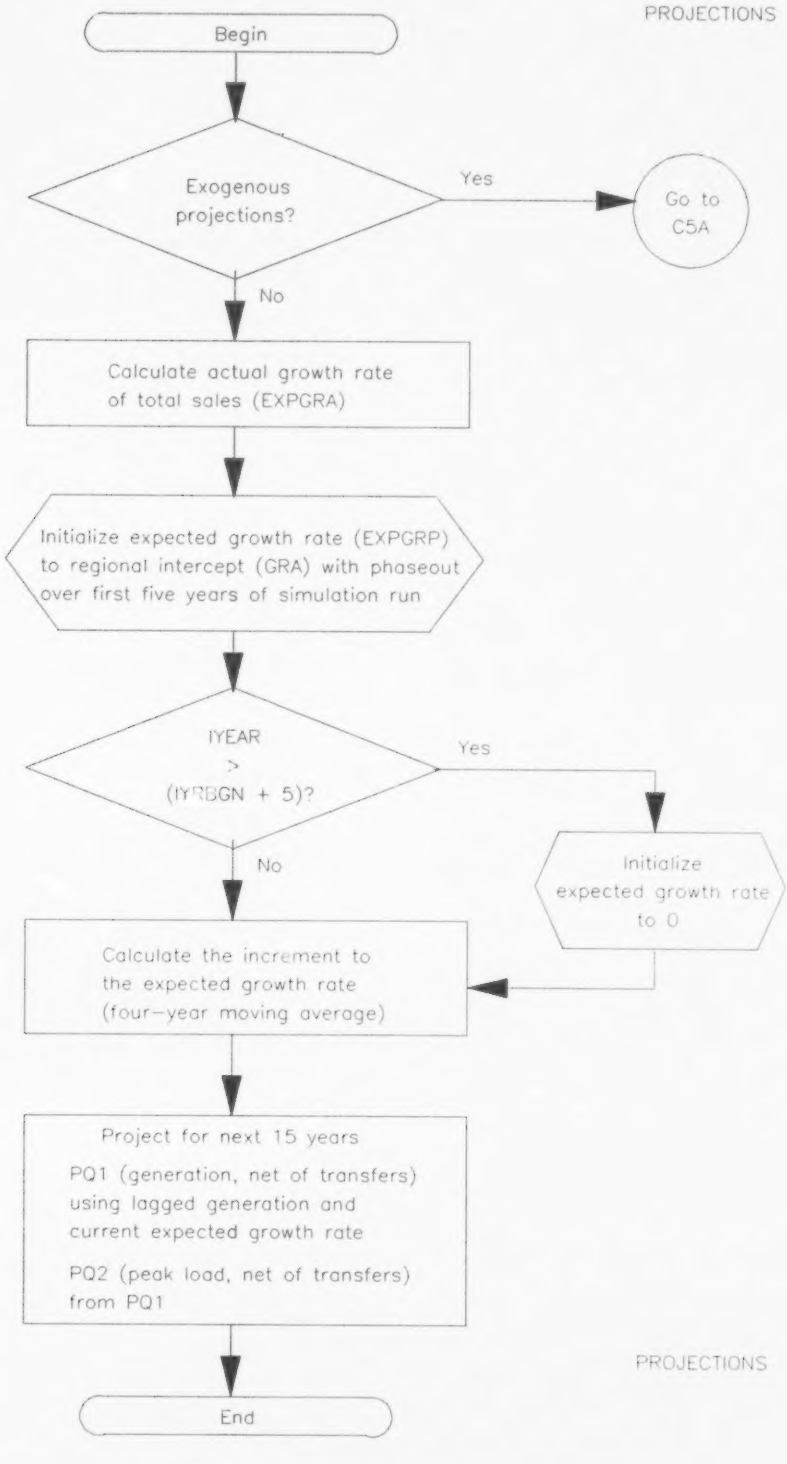
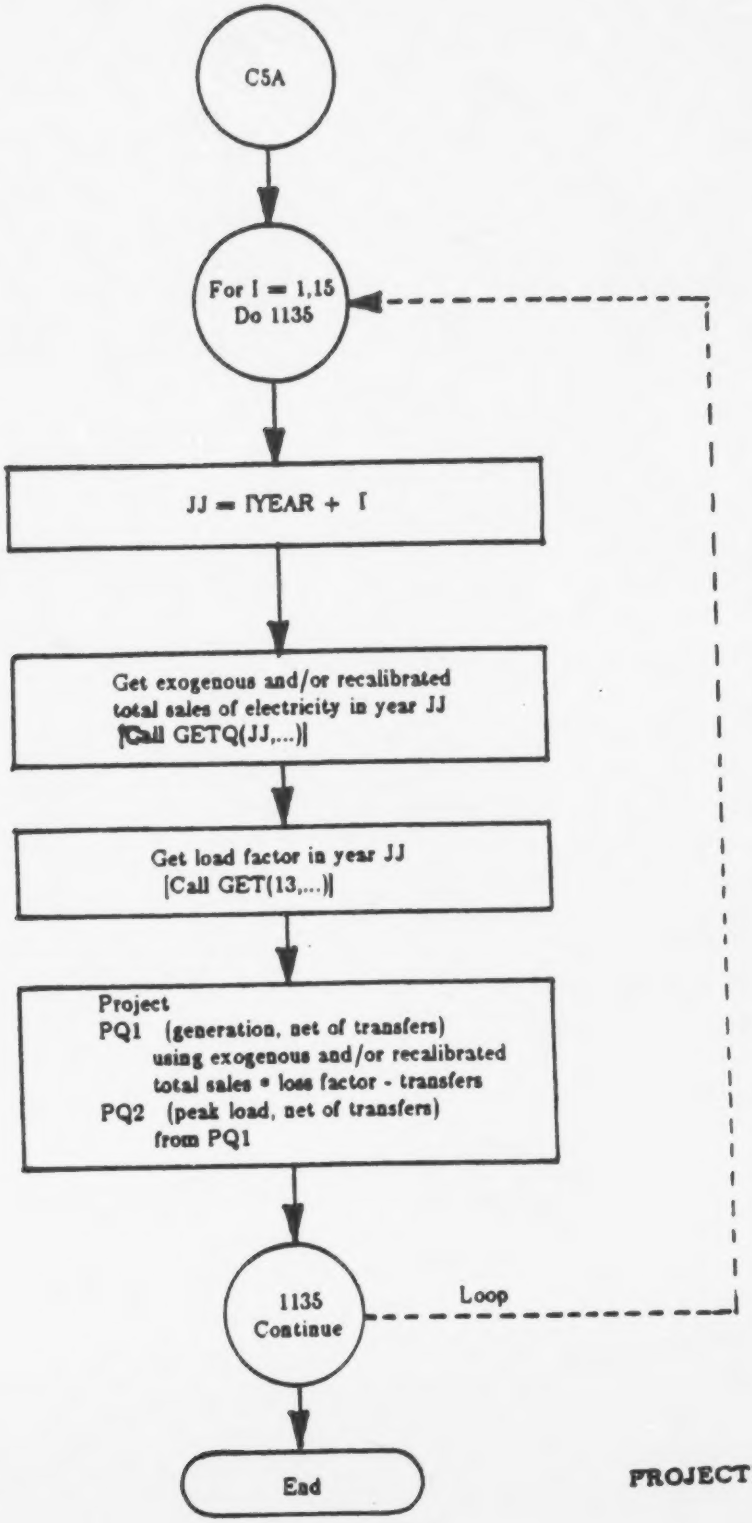

PROJECTIONS
Begin
Exogenous projections?
Yes
Go to C5A
No
Calculate actual growth rate of total sales (EXPGRA)
Initialize expected growth rate (EXPGRP) to regional intercept (GRA) with phaseout over first five years of simulation run
IYEAR > (IYRBGN + 5)?
Yes
Initialize expected growth rate to 0
No
Calculate the increment to the expected growth rate (four–year moving average)
Project for next 15 years
PQ1 (generation, net of transfers) using lagged generation and current expected growth rate
PQ2 (peak load, net of transfers) from PQ1
PROJECTIONS
End

Figure C4-3 (contd.)


C5A
For I = 1,15
Do 1135
JJ = IYEAR + I
Get exogenous and/or recalibrated
total sales of electricity in year JJ
[Call GETQ(JJ,...)]
Get load factor in year JJ
[Call GET(13,...)]
Project
PQ1 (generation, net of transfers)
using exogenous and/or recalibrated
total sales * loss factor - transfers
PQ2 (peak load, net of transfers)
from PQ1
1135
Continue
Loop
End

PROJECTIONS

Figure C4–4
SUBROUTINE GETQ FLOWCHART

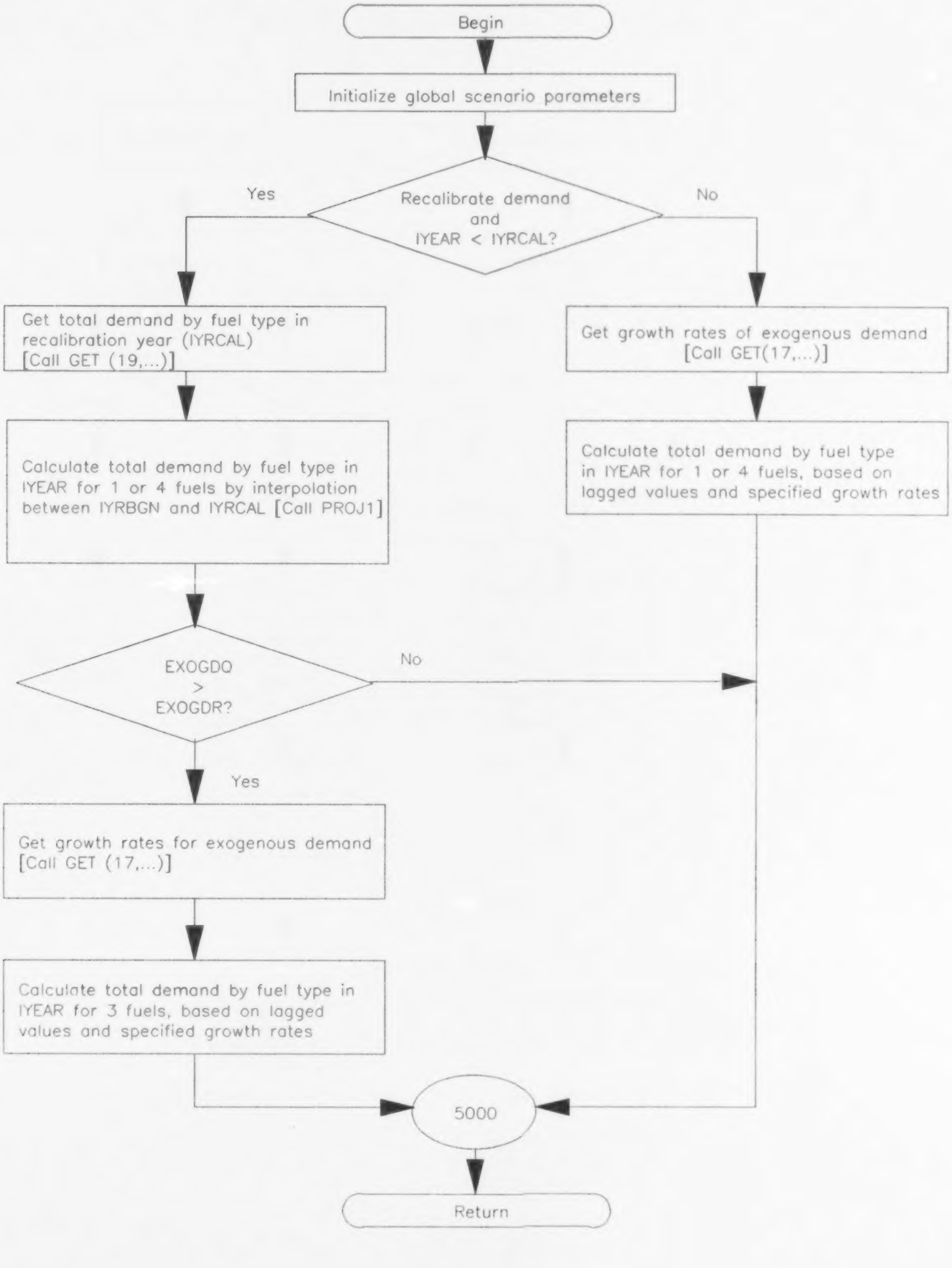

Begin
Initialize global scenario parameters
Yes
Recalibrate demand and IYEAR < IYRCAL?
No
Get total demand by fuel type in recalibration year (IYRCAL) [Call GET (19,...)]
Calculate total demand by fuel type in IYEAR for 1 or 4 fuels by interpolation between IYRBGN and IYRCAL [Call PROJ1]
Get growth rates of exogenous demand [Call GET(17,...)]
Calculate total demand by fuel type in IYEAR for 1 or 4 fuels, based on lagged values and specified growth rates
EXOGDQ > EXOGDR?
No
Yes
Get growth rates for exogenous demand [Call GET (17,...)]
Calculate total demand by fuel type in IYEAR for 3 fuels, based on lagged values and specified growth rates
5000
Return

Figure C4-5
SCHEMATIC REPRESENTATION OF EXOGENOUS DEMAND AND RECALIBRATION OF DEMAND

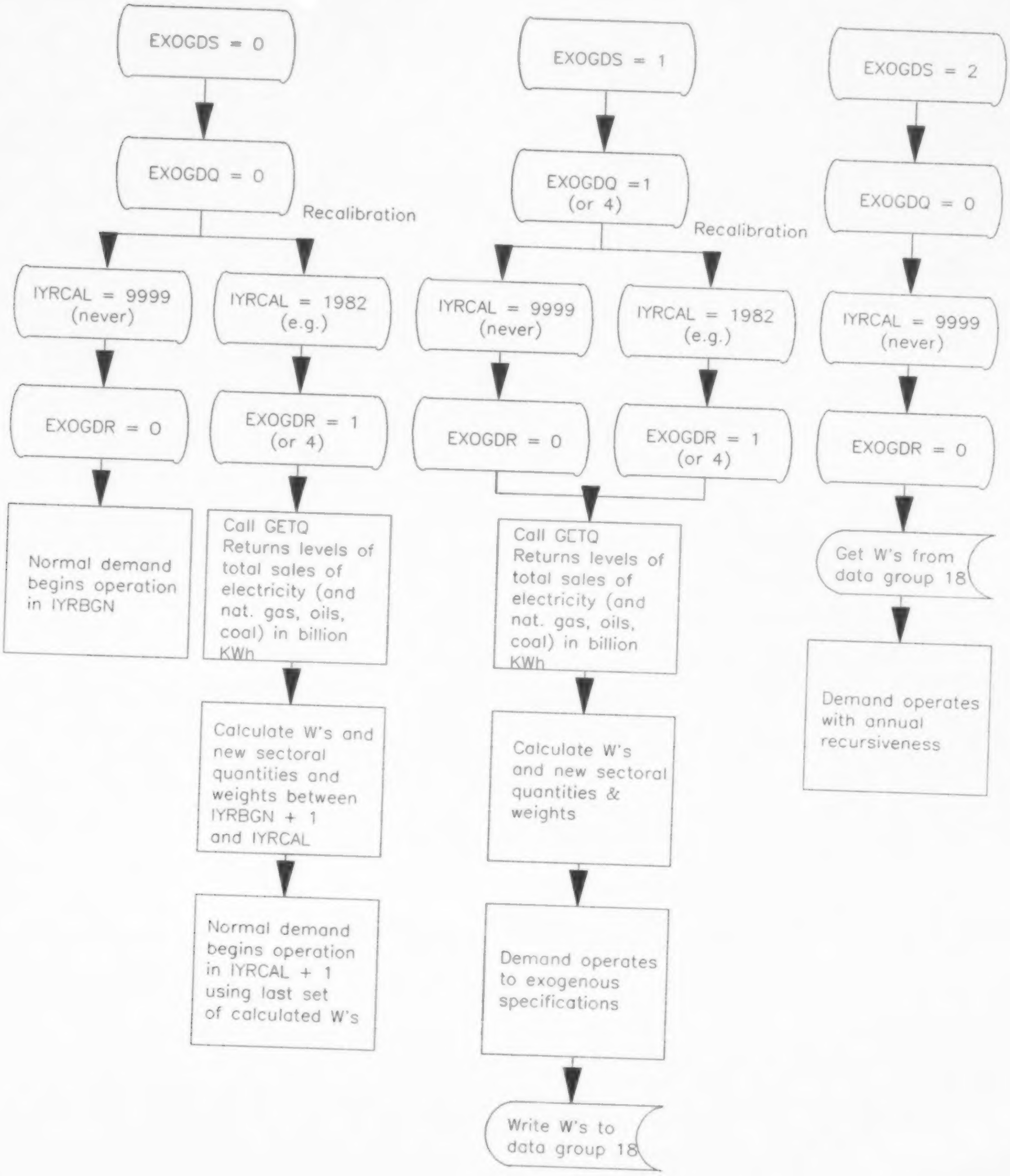

EXOGDS = 0
EXOGDQ = 0
Recalibration
IYRCAL = 9999 (never)
IYRCAL = 1982 (e.g.)
EXOGDR = 0
EXOGDR = 1 (or 4)
Normal demand begins operation in IYRBGN
Call GETQ Returns levels of total sales of electricity (and nat. gas, oils, coal) in billion KWh
Calculate W's and new sectoral quantities and weights between IYRBGN + 1 and IYRCAL
Normal demand begins operation in IYRCAL + 1 using last set of calculated W's
EXOGDS = 1
EXOGDQ =1 (or 4)
Recalibration
IYRCAL = 9999 (never)
IYRCAL = 1982 (e.g.)
EXOGDR = 0
EXOGDR = 1 (or 4)
Call GETQ Returns levels of total sales of electricity (and nat. gas, oils, coal) in billion KWh
Calculate W's and new sectoral quantities & weights
Demand operates to exogenous specifications
Write W's to data group 18
EXOGDS = 2
EXOGDQ = 0
IYRCAL = 9999 (never)
EXOGDR = 0
Get W's from data group 18
Demand operates with annual recursiveness

Table C4-1
CORRESPONDENCE CHART FOR FUEL PRICES

Fuel	P	P3
Nuclear	1	5
Coal	2	CPRICE
Distillate oil	3	2
Residual oil	4	1
Natural gas	5	3
Other	6	6
Gasoline	7	4

Table C4-2
CORRESPONDENCE CHART FOR DEMAND MODEL INPUTS

	Industrial			*Residential or Total*			
Input Variables	PRICIN	P	P2	PRICIN	P	P2	P0
Price of natural gas	4,3	5					
Price of distillate oil	5,3	3					
Price of residual oil	6,3	4					
Price of gasoline			7,1		7		
Price of coal	9,3	2					
Employment	12,3		3		12,1	4	
Personal income					13,1	1	
Population					14,1	2	
Price of appliances index					15,1		1
Price of new cars index					16,1		2
Price of nonfuel expenditures index					17,1		3

	Industrial		*Commercial*		*Residential*	
Demand Variables	VRATIO	P1	VRATIO	P1	VRATIO	P1
Price of natural gas	4,3	33	4,2	18	4,1	3
Price of distillate oil	5,3	34	5,2	19	5,1	4
Price of residual oil	6,3	35	6,2	20		
Price of gasoline					7,1	6
Price of coal	9,3	37				
Price of labor	11,3	38	11,2	23		
Employment	12,3	39	12,2	24		
Per capital disposable income					13,1	10
Population					14,1	11
Price of appliance index					15,1	12
Price of new cars index					16,1	13
Price of nonfuel expenditures index					17,1	14

Table C4-3
CALIBRATION CHART

	Industrial		*Commercial*	
	VRATIO	Calculation	VRATIO	Calculation
Price of natural gas	4,3	P1(33)-P(5)	4,2	P1(18)-P1(33)
Price of distillate oil	5,3	P1(34)-P(3)	5,2	P1(19)-P1(34)
Price of residual oil	6,3	P1(35)-P(4)	6,2	P1(20)-P1(35)
Price of coal	9,3	P1(37)-P(2)		
Employment	12,3	P1(39)/ ((P2(3)•52/ P2(2))	12,2	P1(24)/ (((P2(4)-P2(3)) •52)/P2(2))

	Residential	
	VRATIO	Calculation
Price of natural gas	4,1	P1(3) -P1(33)
Price of distillate oil	5,1	P1(4) -P1(34)
Price of gasoline	7,1	P1(6) -P(7)
Per capita disposable income	13,1	P1(10)/((P2(1)/P2(2)) • 1000)
Population	14,1	P1(11)/P2(2)
Price of appliances index	15,1	P1(15)/P0(1)
Price of new cars index	16,1	P1(16)/P0(2)
Price of nonfuel expenditures index	17,1	P1(17)/P0(3)

Note: Calibration factors (VRATIO) are calculated in the first year, by state.

Table C4-4
CORRESPONDENCE CHART FOR DEMAND MODEL COMPONENTS

N

——P1S(N,NS)——

——Q1S(N,NS)——

NS	EL	NG	OL	OH	OM	CL	OTH	INC	APP	CAR
1	1	2	3		4		5	6	7	8
2	1	2	3	4			5			
3	1	2	3	4		5	6			
4	1									
5	1									

—COEFF(N,NEQS,NS) and V(N,NEQS,NS)——

NEQS	NS	EL	NG	OL	OH	OM	CL	OTH	INC	APP	CAR	QP
1	1	1	2	3		4		5	6	7		9
2	1	1	2	3		4		5	6			9
3	1	1	2	3		4		5	6			9
4	1	1	2	3		4		5	6		8	9
1	2	1	2	3	4			5				6
2	2	1	2	3	4			5				6
3	2	1	2	3	4			5				6
4	2	1	2	3	4			5				6
1	3	1	2	3	4		5	6				7
2	3	1	2	3	4		5	6				7
3	3	1	2	3	4		5	6				7
4	3	1	2	3	4		5	6				7
5	3	1	2	3	4		5	6				7

Note:
P1S = Prices
Q1S = Quantities
COEFF = Coefficients
V = Variables
NEQS = Equation number

Table C4-4 (contd.)

NS = *Sector number where* *1* = *Residential*
2 = *Commercial*
3 = *Industrial*
4 = *Transportation*
5 = *Total*

EL = *Electricity*
NG = *Natural gas*
OL = *Distillate oil*
OH = *Residual oil*
OM = *Gasoline*
CL = *Coal*
OTH = *Other (i.e., nonfuel, for residential sector only; labor for commercial and industrial sectors)*
INC = *Per capita disposable income less customer charge*
APP = *Price of appliances index*
CAR = *Price of new cars index*
QP = *Lagged per capita quantity ratio*

Table C4-5

PROGRAM DEMAND: VARIABLE DESCRIPTIONS

Variable	Unit	Description
ADJF		Revenue adjustment factor (fuel) (state specific)
ADJNF		Revenue adjustment factor (nonfuel) (state specific)
AINTER		Demand model intercepts (state specific, equation specific, and sector specific)
AOM	Million $	Cost of labor and O&M
APE	$/MKWh	Overall average price of electricity
APES	$/MMBtu	Sectoral average prices of electricity
APESM	$/MMBtu	Temporary variable; see APES
AVCOST	$/MKWh	Average cost of service
AVFC	$/MKWh	Average cost of fuel per KWh generated, adjusted by LOSSF
AVNFC	$/MKWh	Average nonfuel cost (APE-AVFC)
A1		Unused
A13		Unused
A2		Unused
A3		Unused
A4		Unused
A5		Unused
A9		Unused
B		Fraction for pegging (sectoral demand model) prices of natural gas to distillate oil such that PNG is less than or equal to B * POL (default B = 1)
C		Demand model coefficients input vector
COEF		Demand model coefficients array (equation and sector specific)
COEFN		Number of coefficients per sector (maximum 15)
CPRICE		Coal price

Table C4-5 (contd.)

Variable	Unit	Description
C2		Conversion factor (3.412)(3412 Btu per KWh)
C5		Conversion factor (1000)
C6		Conversion factor (1,000,000)
C7		Unused
DEFL		Inflation factor
DG10		Data group 10 input vector
DG11		Data group 11 input vector
DG12		Data group 12 input vector
DG13		Data group 13 input vector
DG14		Data group 14 input vector
DG15		Data group 15 input vector
DG16		Data group 16 input vector
DG63		Data group 63 input vector
DG74		Data group 74 input vector
DG18		Data group 18 input vector
EARNR		Ratio of earnings per capita to per capita disposable income
ECOST	$/MMBtu	Sectoral extra fuel cost
EQS		Number of equations per sector (maximum 5)
EXDQ		Exogenous demand quantities switch for specifying expected growth rates for total sales by fuel type: 0 = Do not specify 1 = Specify for electricity 2 = Specify for electricity, natural gas, oils, and coal
EXDR		Demand recalibration switch for specifying actual levels of total sales by fuel type (values as under EXDQ, above)
EXOGDQ		Same as EXDQ

Table C4-5 (contd.)

Variable	Unit	Description
EXOGDR		Same as EXDR
EXOGDS		Exogenous demand switch: 0 = Normal operation 1 = Specify expected demand growth rates for total sales of electricity (natural gas, oils, and coal), calculate adjustments to demand model intercepts (W), and write to data group 18 for input to another (policy) run 2 = Exogenous demand with annual recursiveness (get adjustments to intercepts from a previous run) 3 = Exogenous demand and plan
EXPGRA	Percent	Actual annual growth rate for total sales
EXPGRP	Percent	Expected annual growth rate for total sales
F		Log share ratio functions
FCNEW	Million $	Total fuel cost at current year's prices
FCOLD	Million $	Total fuel cost at previous year's prices
FPESC	$/MMBtu	Fuel price escalation
FUELC	$/MKWh	Average cost of fuel per KWh sold
GRA		Projection factor (regional)
GRB		Projection model coefficients
GRC		Projection model coefficients
IGSA		Number of variables per sector (maximum 20)
IGSC		Same as COEFN
ISTATE	Codelist 1	Current state code number (first argument in module call)
ISTOP		Error flag
ITRACE		Run-time trace option (third argument in module call)
IYEAR	Year	Current simulation run year (second argument in module call)
IYRBGN	Year	First year in simulation run

Table C4-5 (contd.)

Variable	Unit	Description
IYRCAL	Year	Recalibration year
IYRCOE	Year	Constant input year economic scenarios
IYRCOF	Year	Constant input year fuel price scenarios
IYREND	Year	Last year of simulation run
IYREXE	Year	Beginning year for economic scenarios
IYRESF	Year	Beginning year for fuel price scenarios
LOSSF		Loss factor (ratio of total sales to required generation)
LSTSTC		Last state called (initialized at 0)
LSTYRC		Last year called (initialized at 0)
NCALL		National data flag: 0 = Get national data 1 = Do not get national data
NL		Vector of lengths for transfer of demand model coefficients from vector C to array COEF
NOEQS		Same as EQS
NSECT		Same as SECT
NSGT		Array of sectors where RATSFC > 1 - THM
NSLE		Array of sectors where RATSFC ≤ 1 - THM
NSLET		Temporary variable; see NSLE
OC		Unused
OQ	Billion KWh	Lagged total sales of electricity
OQR	Billion KWh	Current and lagged total sales of electricity
P	$/MMBtu	Current year fuel costs
PELIND		Price index for energy relative to inflation (sectoral, raw)
PLOSS	Billion KWh	Losses (required generation–total sales)
PQ1	Billion KWh	Projected energy, net of transfers (15 years)

Table C4-5 (contd.)

Variable	Unit	Description
PQ2	MW	Projected peak load, net of transfers (15 years)
PRICIN	Varied	Demand model input variables (sectoral)
PRN		Same as IGSA
P0		National demand input data[b]
P1		Demand model variable ratios[c]
P1S	$/MMBtu	Demand model prices (sectoral)
P2		State-specific demand input data[d]
P3		Alternate fuel prices[e]
P5		Lagged demand variables[f]
Q	MMBtu/capita	Lagged quantities (sectoral vector)
Q1	Billion KWh	Generation, net of transfers
Q1S	MMBtu/capita	Current fuel quantities (usually calculated by demand model; sector specific)
Q2	MW	Peak load, net of, net of transfers (other load characteristics unused)
Q3	Billion KWh	Transfers; see TRANV
RATNFC		Sectoral ratios of average sectoral nonfuel costs to average nonfuel costs
RATSFC		Sectoral ratios of average cost of fuel to average sectoral prices
RDIF	Million $	Revenue adjustment for 1980 (RV1 - RQ1)
REGHR	$/MMBtu	Regulatory escalation: ADJNF • (RQ1 - RV1)
RETCAP	Million $	Cost of return to capital
RG	Billion KWh	Required generation (total sales • LOSSF)
RGOLD	Billion KWh	Lagged required generation
RN		Adjusted nonfuel escalation factor, REGHR/AVNFC, adjusted for units

Table C4-5 (contd.)

Variable	Unit	Description
RNN	$/MMBtu	Nonfuel component of the marginal price (sectoral)
RQ1	Million $	Total revenue required
RVQPCT	Percent and Million $	Revenue requirements percentages and total revenue required
RV1	Million $	Total revenue received, net of transfers
RV1S	Million $/capita	Revenue received, sectoral, net of transfers
RV3	Million $	Net cost of transfers (total revenue received/expended due to transfers)
SECT		Number of sectors (maximum 4)
SG	Billion KWh	State-level generation (required generation—transfers)
SGOLD	Billion KWh	Lagged state-level generation
SNFC	$/MKWh	Sectoral nonfuel costs
SQLE	$/MKWh	Sectoral rate schedule adjustment factor
SRGT	$/MKWh	Sectoral rate schedule adjustment factor
STRNQR		Transportation quantity ratio
STRNRR		Transportation revenue ratio
TH		1.0 - (AVFC/APE)
THM		0.5 * TH
TQ	Billion KWh	Total sales by fuel type (electricity, natural gas, oils, and coal)
TRANF		Transfer factor (state specific)
TRANV	Billion KWh	Transfer value, at level in first simulation year - (RG * (1.0 - TRANF))
V		Demand model variables (equation and sector specific)
VRATIO		Ratio of initial demand value to interpolated value (state specific), after first year of a run (to begin, contains initial demand value)

Table C4-5 (contd.)

Variable	Unit	Description
W		Adjustments to demand model intercepts due to exogenously specified or recalibrated demand
WAGER		Ratio of commercial to industrial labor price
WT		Cost share ratios (equation and sector specific)
WX		Factor in computing adjustments to intercepts for commercial and industrial sectors
XQ	Billion KWh	Level of sales by fuel type (electricity, natural gas, oils, and coal)
YRCAL		Same as IYRCAL

[a] *See the descriptions of data groups 71 and 75 [2].*

[b] *See the description of data group 11 [2].*

[c] *See the description of data group 12 [2].*

[d] *See the description of data group 13 [2].*

[e] *See the description of data group 74 [2].*

[f] *See the description of data group 16 [2].*

[g] *See the description of data group 63 [2].*

Table C4-6
SUBROUTINE DEMAND: VARIABLE INFORMATION

Variable	Type	Dimension	Storage Location	Accessed from
ADJF	Real	1	/DST/	DG 12 (82)[a]
ADJNF	Real	1	/DST/	DG 12 (85)
AINTER	Real	5,4	/DST/	DG 12 (1-20)
AOM	Real	1	//[b]	
APE	Real	1	//	
APES	Real	4	//	
APESM	Real	1	DEMAND	
AVCOST	Real	1	//	
AVFC	Real	1	//	
AVNFC	Real	1	//	
A1	Real	1	/DNAT/	DG 10 (261)
A13	Real	21	/DST/	DG 12 (89-110)
A2	Real	1	/DNAT/	DG 10 (262)
A3	Real	1	/DNAT/	DG 10 (263)
A4	Real	1	/DNAT/	DG 10 (264)
A5	Real	1	/DNAT/	DG 10 (265)
A9	Real	15	/DNAT/	DG 10 (281-295)
B	Real	1		GETSCN(96)[c]
C	Real	255	/DNAT/	DG 10 (1-255)
COEF	Real	15,5,4	/DNAT/	
COEFN[d]	Real	1	/DNAT/	DG 10 (271)
CPRICE	Real	1	DEMAND	
C2	Real	1	/DNAT/	DG 10 (257)
C5	Real	1	/DNAT/	DG 10 (258)
C6	Real	1	/DNAT/	DG 10 (259)
C7	Real	1	/DNAT/	DG 10 (260)
DEFL	Real	1	/DNAT/	GETSCN(54)
DG10	Real	295	/DNAT/	DG 10 (1-295)
DG11	Real	5	/DNATYR/	DG 11 (1-5)
DG12	Real	110	/DST/	DG 12 (1-110)
DG13	Real	5	//	DG 13 (1-5)

Table C4-6 (contd.)

Variable	Type	Dimension	Storage Location	Accessed from
DG14	Real	34	//	DG 14 (1-34)
DG15	Real	8	//	DG 15 (1-8)
DG16	Real	50	//	DG 16 (1-50)
DG63	Real	10	//	DG 63 (1-10)
DG74	Real	6	//	DG 74 (1-6)
DG18[e]	Real	5	//	DG 18 (1-5)
EARNR	Real	1	/DST/	DG 12 (87)
ECOST	Real	3	/DST/	
EQS[f]	Real	4	/DNAT/	DG 10 (267-270)
EXDQ[g]	Real	1	/DNAT/	GETSCN(102)
EXDR[h]	Real	1	/DNAT/	GETSCN(104)
EXOGDQ	Integer	1	/DNAT/	
EXOGDR	Integer	1	/DNAT/	
EXOGDS	Real	1	/DNAT/	GETSCN(101)
EXPGRA	Real	1	//	
EXPGRP	Real	1	//	
F	Real	5	//	
FCNEW	Real	1	//	
FCOLD	Real	1	//	
FPESC	Real	1	//	
FUELC	Real	1	//	
GRA	Real	1	/DST/	DG 12 (83)
GRB	Real	4	/DNAT/	DG 10 (273-276)
GRC	Real	4	/DNAT/	DG 10 (277-280)
IGSA	Integer	1	/DNAT/	
IGSC	Integer	1	/DNAT/	
ISTATE	Integer	1		argument
ITRACE	Integer	1		argument
IYEAR	Integer	1		argument
IYRBGN	Integer	1	/DNAT/	GETSCN(52)
IYRCAL	Integer	1	/DNAT/	GETSCN(103)
IYRCOE	Integer	1	/DNAT/	GETSCN(86)

Table C4-6 (contd.)

Variable	Type	Dimension	Storage Location	Accessed from
IYRCOF	Integer	1	/DNAT/	GETSCN(95)
IYREND	Integer	1	/DNAT/	
IYREXE	Integer	1	/DNAT/	GETSCN(85)
IYREXF	Integer	1	/DNAT/	GETSCN(94)
LOSSF	Real	1	/DNAT/	DG 10 (256)
LSTSTC	Integer	1	/DNAT/	
LSTYRC	Integer	1	/DNAT/	
NCALL	Integer	1	/DNAT/	
NL	Integer	4	/DNAT/	
NOEQS	Integer	4	/DNAT/	
NSECT	Integer	1	/DNAT/	
NSGT	Integer	4	//	
NSLE	Integer	4	//	
NSLET	Integer	4	//	
OC	Real	4	//	DG 14 (31-34)
OQ	Real	5	//	DG 16 (22-26)
OQR	Real	6	//	
P	Real	10	//	
PELIND	Real	4	//	
PLOSS	Real	1	DEMAND	
PQ1	Real	15	//	DG 14 (1-15)
PQ2	Real	15	//	DG 14 (16-30)
PRICIN	Real	20,4	//	
PRN[i]	Real	1	/DNAT/	DG 10 (272)
P0	Real	5	/DNATYR/	DG 11 (1-5)
P1	Real	60	/DST/	DG 12 (21-80)
P1S	Real	15,5	//	
P2	Real	5	//	DG 13 (1-5)
P3	Real	6	//	DG 74 (1-6)
P5	Real	24	//	DG 16 (27-50)
Q	Real	21	//	DG 16 (1-21)
Q1	Real	1	//	DG 15 (1)

Table C4-6 (contd.)

Variable	Type	Dimension	Storage Location	Accessed from
Q1S	Real	6,5	//	
Q2	Real	5	//	DG 15 (2-6)
Q3	Real	1	//	
RATNFC	Real	4	//	
RATSFC	Real	4	//	
RDIF	Real	1	/DST/	
REGHR	Real	1	//	
RETCAP	Real	1	//	
RG	Real	1	//	
RGOLD	Real	1	//	
RN	Real	1	//	
RNN	Real	1	//	
RQ1	Real	1	//	DG 63 (10)
RVQPCT	Real	9	//	DG 63 (1-9)
RV1	Real	1	//	DG 15 (7)
RV1S	Real	6,5	//	
RV3	Real	1	//	DG 15 (8)
SECT[j]	Real	1	/DNAT/	DG 10 (266)
SG	Real	1	//	
SGOLD	Real	1	//	
SNFC	Real	4	//	
SQLE	Real	1	DEMAND	
SRGT	Real	1	DEMAND	
STRNQR	Real	1	/DST/	
STRNRR	Real	1	/DST/	DG 12 (86)
TH	Real	1	DEMAND	
THM	Real	1	DEMAND	
TQ	Real	4	/DST/	
TRANF	Real	1	/DST/	DG 12 (81)
TRANV	Real	1	/DST/	DG 12 (84)
V	Real	15,5,4	//	
VRATIO	Real	20,4	/DST/	

Table C4-6 (contd.)

Variable	Type	Dimension	Storage Location	Accessed from
W	Real	5	/DST/	
WAGER	Real	1	/DST/	DG 12 (88)
WT	Real	6,4	//	
WX	Real	4	/DST/	
XQ	Real	4	/DST/	
YRCAL	Real	1	/DNAT/	

[a] *DG means data group; numbers in parentheses are item numbers (see Reference 3).*

[b] *// denotes location of variable in blank common.*

[c] *GETSCN denotes scenario parameter; numbers in parentheses are item numbers (see Reference 3).*

[d] *Alias is IGSC.*

[e] *Alias is W.*

[f] *Alias is NOEQS.*

[g] *Alias is EXOGDQ.*

[h] *Alias is EXOGDR.*

[i] *Alias is IGSA.*

[j] *Alias is NSECT.*

Table C4-7
SUBROUTINE PRERR: VARIABLE DESCRIPTIONS

Variable	Unit	Description
I		Fuel type indicator (fourth argument in call)
ISTATE	Codelist I	Current state code number (first argument in call)
ISTOP		Error flag
ITYP		Type of warning message indicator (third argument in call) 1 = price reset to 1.0 2 = price reset to another fuel price
IYEAR	Year	Current simulation run year (second argument in call)
J		Sector indicator (fifth argument in call)

Table C4-8
SUBROUTINE PRERR: VARIABLE INFORMATION

Variable	Dimension	Location
I	1	Dummy argument
ISTATE	1	Argument
ISTOP	1	PRERR
ITYP	1	Dummy argument
IYEAR	1	Argument
J	1	Dummy argument

Note: *All variables in subroutine PRERR are of type integer.*

Table C4-9

SUBROUTINE GETQ: VARIABLE DESCRIPTIONS

Variable	Unit	Description
A		For exogenous demand, expected growth rate of total sales
DG17		Data group 17 input vector
DG19	Billion KWh	Data group 19 input vector
EXOGDQ		Exogenous demand quantities switch for specifying expected growth rates for total sales by fuel type: 0 = do not specify 1 = specify for electricity 4 = specify for electricity, natural gas, oils, and coal
EXOGDR		Demand recalibration switch for specifying actual levels of total sales by fuel type; values as under EXOGDQ, above
IGQ		For recalibration, vector of interpolation years where 1 = IYRBGN and 2 = IYRCAL
ISTATE	Codelist I	Current state code number (second argument of call)
IYEAR	Year	Current simulation run year (first argument of call)
IYRBGN	Year	First year of simulation run
IYRCAD	Year	Recalibration year (data group 19)
IYRCAL	Year	Recalibration year
VGQ	Billion KWh	For recalibration, array of levels of total sales
XQ	Billion KWh	Array of level of total sales (third argument of call); output for IYEAR; for exogenous demand, input is value in preceding year; for recalibration, input is value in IYRBGN

Table C4-10

SUBROUTINE GETQ: VARIABLE INFORMATION

Variable	Type	Dimension	Location	Accessed from
A	Real	1	GETQ	
DG17	Real	4		DG 17(1-4)[a]
DG19	Real	4		DG 19(2-5)
EXODGQ	Integer	1	GETSCN(102)[b]	
EXOGDR	Integer	1	GETSCN(104)	
IGQ	Integer	2	GETQ	
ISTATE	Integer	1		
IYEAR	Integer	1		
IYRBGN	Integer	1	GETSCN(52)	
IYRCAD	Integer	1		DG 19(1)
IYRCAL	Integer	1	GETSCN(103)	
VGQ	Real	2,4	GETQ	
XQ	Real	4	GETQ	

[a] *DG means data group; numbers in parentheses are item numbers (see Reference 3).*

[b] *GETSCN denotes scenario parameters; numbers in parentheses are item numbers (see Reference 3).*

REFERENCES

1. Bruce Hannon, Randall Jackson and Douglas Kennedy. **"Advanced Utility Simulation Model, Energy and Employment Impacts Module (Version 1.0)."** U.S. Environmental Protection Agency. EPA-600/8-88-071g (NTIS PB89-126569). October 1988.

2. James J. Stukel. **"Advanced Utility Simulation Model, Analytical Documentation, State Level Model (Version 1.0)."** U.S. Environmental Protection Agency. EPA-600/8-88-071a. January 1989.

3. Caroline J. Badger and Howard Ojalvo. **"Advanced Utility Simulation Model, Documentation of System Design, State Level Model (Version 1.0)."** U.S. Environmental Protection Agency. EPA-600/8-88-071c (NTIS PB89-101208). August 1988.

C5. THE CAPACITY PLANNING MODULE

by
Beth Engelbrecht-Wiggans, Howard Ojalvo and Kevin Welch

Universities Research Group on Energy
University of Illinois at Urbana-Champaign

5.1 Overview

The central task of the capacity planning module of the Advanced Utility Simulation Model (AUSM) is to maintain a schedule for the construction of electric power plants that best matches the capacity needs implied by the computer simulation in progress. Capacity requirements are based on the demand for electricity calculated by the demand module on an annual basis. This demand is projected over a look-ahead horizon equal to the maximum plant construction period. PLAN, the supervisory routine for this module, sets up the initial construction schedule in year 1 by cataloguing plants (from data group 23)[1] in the initial unit inventory file (from data group 70), which are slated with a future on-line date.

For each year that PLAN is run, a two-part capacity needs test is performed successively for each year in the look-ahead horizon. If both parts are passed, steps are taken to defer plants under construction (subroutine DEFER). Otherwise, capacity augmentation is undertaken (subroutine ADVANC).[2]

The objective of defer is to delay construction on plants that would otherwise be brought on-line in the current horizon year. Construction is deferred on as many plants as possible without failing any part of the capacity needs test.

Subroutine ADVANC is called if either part of the capacity needs test fails. It consists of two phases: (1) advancement of scheduled plants and (2) scheduling of new plants. The scheduling phase takes place only if sufficient capacity cannot be brought on-line in the current horizon year by advancing scheduled plants. Either phase stops when sufficient capacity has been added to pass all three tests in the horizon year.

---

[1] Numbers in parentheses refer to data groups in Section 3.2 of the AUSM system design document [1].

[2] It is possible to set a user-specified construction schedule option on the input scenario parameter file, in which case no plants are ever advanced, deferred or scheduled.

Figure C5-1 depicts the control flow of the capacity planning module, and Figure C5-2 summarizes the inputs to and outputs of the module.

5.2 Central Algorithms and Basic Assumptions

5.2.1 The Two-Part Capacity Needs Test

In year k, success in each part of the capacity needs test is defined as follows:

1. Energy requirements can be met without overusing peaking plants:

$$\sum_{i=1}^{ntech} (C_{ik} * F_i * 8760 > Q_k$$

2. The peak load test on a typical peak season weekday can be met by available capacity:

$$\sum_{i=1}^{ntech} (C_{ik} * A_i) > P_k$$

where $ntech$ = number of plant construction technologies

C_{ik} = capacity in year k of plants of technology i (MW)

P_k = peak load in year k (MW)

A_i = availability of plant type i

F_i = maximum capacity factory for plant type i

Q_k = quantity of electricity in year k (MWh)

Before carrying out the scheduling algorithm in a given year (IYR), PLAN gains access to the following data from the demand module via data group 13:

Figure C5-1
SUMMARY OF CAPACITY PLANNING CONTROL FLOW

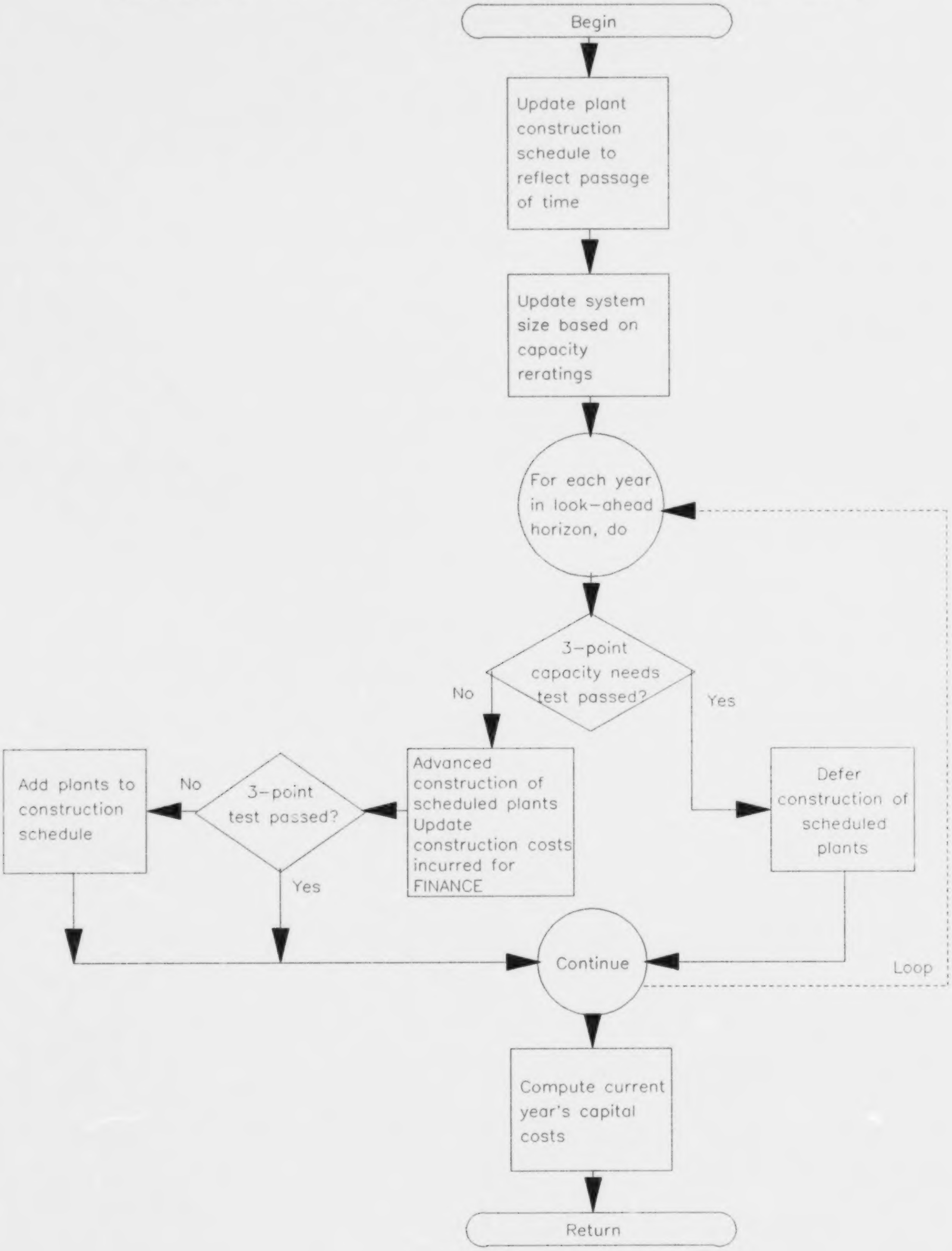
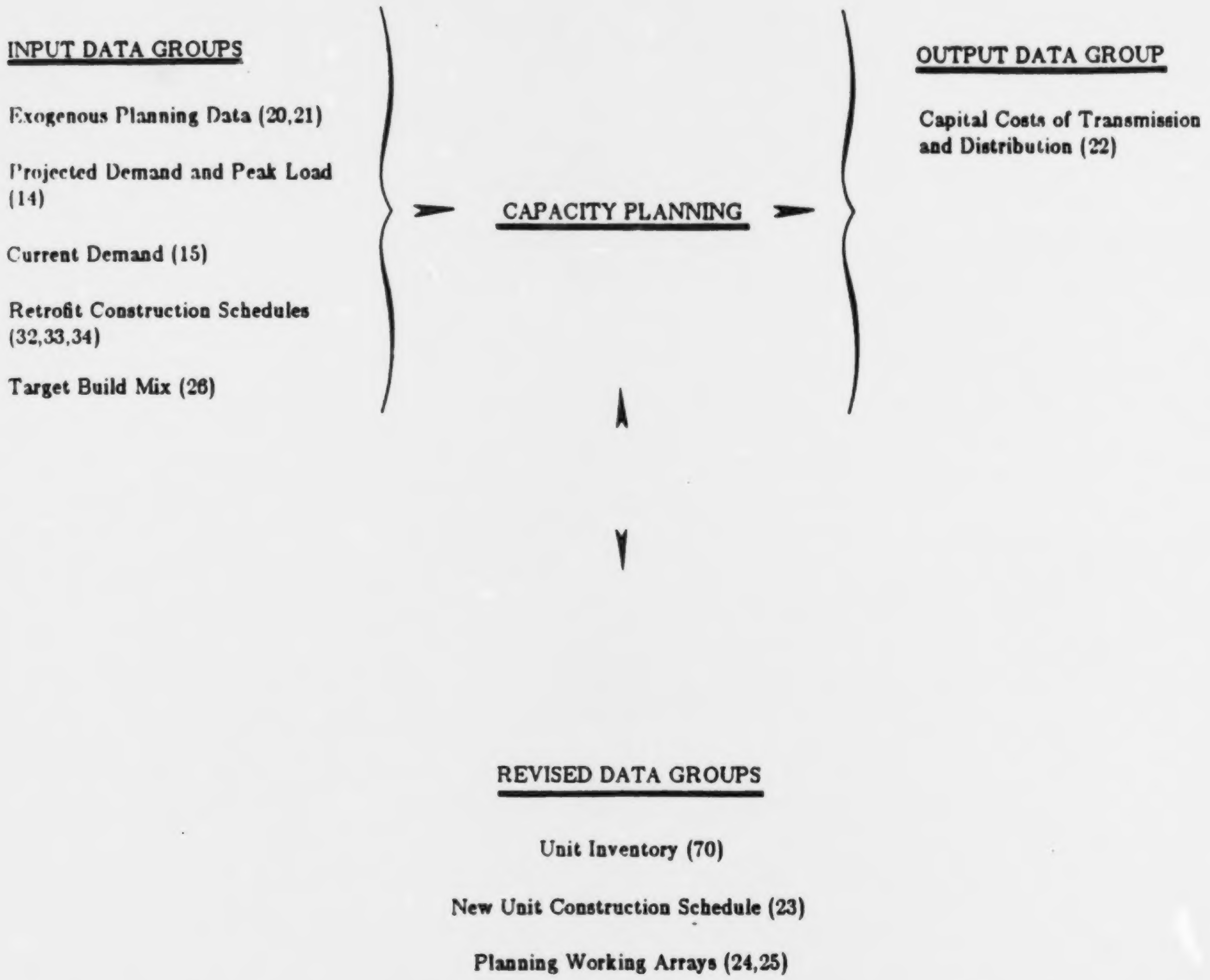

Begin
Update plant construction schedule to reflect passage of time
Update system size based on capacity reratings
For each year in look-ahead horizon, do
3-point capacity needs test passed?
No
Yes
Advanced construction of scheduled plants Update construction costs incurred for FINANCE
Defer construction of scheduled plants
No
3-point test passed?
Yes
Add plants to construction schedule
Continue
Loop
Compute current year's capital costs
Return

Figure C5-2
SUMMARY OF CAPACITY PLANNING INPUTS AND OUTPUTS


INPUT DATA GROUPS
Exogenous Planning Data (20,21)
Projected Demand and Peak Load (14)
Current Demand (15)
Retrofit Construction Schedules (32,33,34)
Target Build Mix (26)
CAPACITY PLANNING
OUTPUT DATA GROUP
Capital Costs of Transmission and Distribution (22)
REVISED DATA GROUPS
Unit Inventory (70)
New Unit Construction Schedule (23)
Planning Working Arrays (24,25)

$$(P_k,\ Q_k,\ k = IYR\ IYR + 11)$$

The two measures of system size correspond to the lefthand sides of the two tests. They are, respectively, energy requirements (AVALMW) and peak power (AVAKWH). These measures of system size are initialized during a first scan of unit inventory to reflect the current system size over a 41-year period (11-years beyond the maximum simulation period), to allow representation of construction starts for plants having 11-year construction periods). System size accumulations are updated each time alterations are made to the plant construction schedule (data group 23).

The array EXCESS(2) contains the differences between projected needs and projected capacity. The components of this array correspond to the two tests. For horizon year k of simulation year IYR,

$$EXCESS_{i=1,2} = C_{i,k+IYR} - D_{i,k+IYR} > 0$$

where $C_{i,k+IYRFrin}$ =projected system size as defined by test i in horizon year k

$D_{i,k+IYR}$ = projected demand as defined by test i in horizon year k

Alterations made to the construction schedule affect the value of $C_{i,k+IYR}$ and are carried out with the goal of bringing each value of EXCESS as close as possible to zero. The tests are considered passed if the value of EXCESS is positive and less than 2 percent of projected capacity. As described in the next two sections, schedule alterations are made by deferring or advancing scheduled plants or by adding new plants to the construction schedule.

5.2.2 Advancement and Additions of Scheduled Plants

Subroutine ADVANC is called each horizon year in which there is insufficient projected capacity to pass all two parts of the capacity needs test. If sufficient capacity cannot be brought on-line in the current horizon year by advancing plants currently scheduled, new plants are slated for construction. Plants are always advanced or scheduled so as to be brought on-line in the horizon year.

The entire list of scheduled plants is examined for possible advancement. Candidates are selected if they meet four criteria:

–The scheduled year on-line is later than the horizon year,

–Enough years remain prior to the horizon year to complete construction,

–If a nuclear plant, either construction is more than the scenario-specified percentage from completion or a user-specified "new nuclear year" has passed,

–The scheduled plant is not an existing plant scheduled for conversion from oil to coal.

In addition, there is a scenario parameter (BDYR) which specifies a year before which no unit may be advanced or scheduled. If the current year is less than this year, the advancement and addition phase is skipped. The only plants that may be advanced under these conditions are those that have previously been deferred. It should be emphasized that this parameter refers to the current year (IYEAR) and not to the horizon year (KHRZ).

Among the group of candidates, plants whose construction has been deferred are ranked before those whose construction has not yet begun. Deferred plants are ranked for advancement in descending order of construction costs incurred to date. The remaining (nondeferred) candidates are ranked as a function of the combination of tests failed. Specifically, if test 1 has failed, then base/intermediate plants are ranked before peakers. If test 2 has failed, then peakers are given the higher priority.

ADVANC selects the technology of new plants with the object of matching the user-specified future mix. However, the decision to add new nuclear plants may not be made before the new nuclear year. Also, a technology may not be selected if there is insufficient time to build that type of plant prior to the horizon year.

The technology mix of plants added to date is maintained in data group 25. The file shows total new capacity and a breakdown of new capacity by technology.

A plant of technology k is selected for scheduling if

$$F_k - \frac{MW_k}{MW_T} > (F_i - \frac{MW_i}{MW_t}) \text{ for } all \text{ } i \neq k$$

where F_k = the user-specified future mix for plant technology k

MW_k = the new generation of type k scheduled to date

MW_T = the total new generation scheduled to date.

Newly scheduled plants are added to the unit inventory file at the same time that they are added to the construction schedule.

5.2.3 Deferral of Scheduled Plants

Subroutine DEFER selects candidates for deferral if they meet the following criteria:

–They are scheduled to be brought on-line in the horizon year,

–They are less than a user-specified percentage from completion by total construction expenditure,

–They are not existing plants scheduled for oil-to-coal conversion.

–In addition, there is a scenario parameter (BPOLD) which sets a deferral cutoff year for baseload plants (i.e., those with technology codes of 15, 16, 17 or 18). If the on-line year of a plant is less than the specified cutoff year, that plant may never be deferred.

Candidates are ranked in ascending order of construction expenditures to date.

Plants are deferred until either (1) all candidates have been deferred or (2) the deferral of any remaining candidate would cause one or more parts of the capacity needs test to fail. If deferral of the high-priority plant would cause failure of the two-part test, a plant ranked low on the list would be deferred and a large high-priority plant would be completed.

Plants are deferred so as to be brought on-line one year after the horizon year. Since plants are selected for deferral only if they are scheduled to be on-line in the current horizon year, it follows that, in a single horizon year, plant construction may be deferred by one year at most. However, plant deferral upon completion of the full scheduling algorithm may total several years.

5.2.4 Pollution Penalties

Construction schedule modifications are based on total generation computed after allowances have been made for pollution control devices. These pollution penalty adjustments are made at the beginning of simulation years in which existing plants are retrofitted for pollution control and new plants with pollution control devices are brought on-line.

In subroutine POLPEN, data groups 32, 33, and 34 are scanned in order to identify plants newly retrofitted with sulfur dioxide, nitrogen oxide, or particulate control devices, respectively. For each device added, the retirement date of the corresponding plant is retrieved from the unit inventory file (data group 70), and system size arrays (data group 24) are reduced for the remaining lifetime of the plant. A similar procedure is carried out in subroutine UPSCHD to update system size to reflect reduced capacity from pollution control devices on new plants.

5.2.5 Transmission, Distribution, and General Administration Costs

In every simulation year, PLAN updates data group 22 with current construction expenditures for transmission, distribution, and general plant administration. These values are calculated as follows:

$$T = PMAX * TC$$

$$D = G * DC$$

$$O\&M = G * GNAC$$

where T = current year's construction expenditures for transmission ($)

$PMAX$ = increase in peak demand since maximum annual last peak year (MW)

TC = transmission cost ($/MW)

D = current year's construction expenditures for distribution ($)

G = increase in net generation since last peak year (MWh)

DC = distribution cost ($/MWh)

$O\&M$ = current year's general and administration expenditures ($)

$GNAC$ = general and administration costs ($/MWh)

5.2.6 Nuclear Moratorium

PLAN uses two scenario variables to simulate the effect of a moratorium on the construction of nuclear plants. The variable NEWNUC defines a year before which nuclear plants may not be scheduled. This allows the user to specify a nuclear moratorium. To deal with plants already under construction, the variable NUCFRC defines a user-specified fraction of construction costs that must have been completed if construction of a nuclear plant will be continued prior to the "new nuclear year."

5.2.7 MPMS Implementation

The MPMS implementation involves two modifications to the target build mix. First, the technology mix supplied by MPMS replaces the user specified technology mix in data group 26. Second, two capacity/demand ratios are supplied in data group 37. These are used to modify the projected demands in the capacity tests for any given horizon year. Two variables are used to represent these ratios. DMULT represents maximum generation/annual generation requirements. PRJQEL is multiplied by DMULT before being subtracted from AVAKWH in capacity test 1. EMULT represents available capacity/peak demand. PRJPLD is multiplied by EMULT before being subtracted from AVALMW in capacity test 2.

If the MPMS switch on the E8 parameter file is set equal to 0, both DMULT and EMULT are always set equal to 1 and hence have no effect on the capacity tests.

5.3. Data Handling

5.3.1 Exogenous National Data

National data in PLAN are accessed from data group 20 the first time that the routine is called. These data are stored unchanged throughout the duration of the simulation in common block PLNATL. National data are organized by plant construction technology code (codelist B; see Reference 1). The 12 items associated with each of the 23 technologies are also catalogued in Reference 1. The variable names actually used are also shown. National construction cost spread data are accessed from data group 20 and stored in common block PLNATL.

5.3.2 Exogenous State Data

State data are accessed from data group 21 when PLAN begins processing a new state. The state-based items along with variable names are catalogued in the AUSM system design document [1]. These variables are retained in common block PLNSTA. PLNSTA also stores PEAKMX (the greatest state yearly peak demand in kilowatts to date) and GENETL (previous maximum generation net of transfers).

5.3.3 Unit Inventory and Construction Schedule

In year 1, PLAN scans the initial unit inventory in order to set up an initial construction schedule for the state in progress. This initial version of the construction schedule is drawn from plants which, at the beginning of the simulation, have an announced on-line date. PLAN makes no changes to the unit inventory at this time except to set the on-line year to 9999.

The progress a plant is making toward completion is defined by three items in the construction schedule: (1) YRBGUN, the year construction begins; (2) YRONSC, the proposed on-line date; and (3) STAGE, the number of construction years completed at the close of the current year.

The total number of stages (or years) required for completion is given by exogenous national input (data group 20) as determined by the technology of the plant under construction. YRONSC is defined as the next year after the last stage has been completed.

Subroutine UPSCHD updates entries in the construction at the beginning of each year to reflect the passage of time. In addition, UPSCHD resets the on-line year and retirement year in the unit inventory when a plant comes on-line. The control program removes an entry from the construction schedule one year after a plant comes on-line.

A new entry is created in the unit inventory for each plant added to the construction schedule. The year on-line for such an entry is dummy-set to 9999.

The construction schedule is accessed from data group 23; the unit inventory, from data group 70. PLAN accesses only the first 22 items pertaining to an entry in the unit inventory. (A twenty-third item, the oil-to-coal conversion flag, is computed from the unit identification number.) Both data group 23 and data group 70 are catalogued in the AUSM system design document along with the variable names used in PLAN. The variables that define entries in both data groups are kept in blank common.

5.3.4 System Size Data

PLAN maintains three arrays to track projected capacity and energy. This information is kept over a 45-year period, reflecting 15 years beyond the 30-year AUSM. System size data are stored in three arrays in PLAN—SYSIZE(45), AVALMW(45), and AVAKWH(45)—which are kept in blank common. Before the scheduling algorithm begins, these arrays are retrieved from data group 25. Data group 25 is replaced prior to exit.

SYSIZE, AVALMW, and AVAKWH are initialized during the first scan of the unit inventory and are updated to reflect any adjustments made to the construction schedule. The system size arrays are also updated in subroutine POLPEN to reflect capacity penalties incurred when new pollution control devices are brought on-line.

5.3.5 Future Mix Data

PLAN selects the technology types of plants added to the construction schedule based on the breakdown by plant technology of capacity added to date. A working copy of this information is updated in blank common each time a plant is scheduled. Upon entering PLAN, the current breakdown is read from data group 25; the updated breakdown is written back upon exiting. The items associated with data group 25 along with the variable names used are catalogued in the AUSM system design document.

5.4 Subroutine Summaries

Synopses and calling sequences of capacity planning subroutines appear in Table C5-1. These subroutines are summarized in Sections 5.4.1 through 5.4.13, below.

Table C5-1
SUBROUTINE SYNOPSES AND CALLING SEQUENCES

Subroutine	Synopsis	Calling Sequence
ADVANC	Supervises advancement of scheduled plants and addition of new plants to the plant construction schedule	ADVANC←PLAN
ARANK	Selects advanceable plants from construction schedule and ranks them for possible advancement	ARANK←ADVANC←PLAN
CUPDAT	Updates the system size arrays and the capacity/demand differential arrays to reflect any changes made to the construction schedule	CUPDAT←ADVANC←PLAN CUPDAT←DEFER←PLAN
DEFER	Supervises deferral of plants in construction schedule	DEFER←PLAN
DRANK	Selects deferrable plants from construction schedule and ranks them for possible deferral	DRANK←DEFER←PLAN
NEWPLT	Assigns initial properties to plants added to unit inventory	NEWPLT←ADVANC←PLAN
NEWSCH	Assigns initial properties to plants added to plant construction schedule	NEWSCH←ADVANC←PLAN NEWSCH←PLAN
NUCSTG	Returns the stage of construction that a plant must have reached if construction may be completed prior to the "new nuclear year"	NUCSTG←UPSCHED←PLAN NUCSTG←ARANK←ADVANC←PLAN
NYDEFD	Returns the number of years construction has been deferred on a scheduled plant	NYDEDF←ADVANC←PLAN NYDEFD←ARANK←ADVANC←PLAN
PLAN	Supervisory routine for the capacity planning module	POLPEN←PLAN
POLPEN	Updates system size arrays to reflect reduced capacity due to installation of pollution control devices	POLPEN←PLAN

Table C5-1 (contd.)

Subroutine	Synopsis	Calling Sequence	
	TDGNA	Computes yearly capital expend- itures for transmission, dis- tribution, and general plant	TDGNA←PLAN
	UPSCHD	Updates entries in construction schedule to reflect beginning of a new year	UPSCHD←PLAN

5.1.1 Subroutine ADVANC

Called by: PLAN.

Calls: ARANK, CUPDAT, NEWPLT, NEWSCH, NYDEFD.

Arguments: KHRZ - Current horizon year.

ISTATE - Current state.

IYEAR - Current simulation year.

ITRACE - Trace level.

Tasks: Supervises augmentation of system size by advancing scheduled plants (phase 1) and by adding new plants to the construction schedule (phase 2). Phase 2 occurs only if sufficient capacity cannot be added in phase 1 to pass all three parts of the capacity needs test. Either phase terminates when system size has been brought up to a sufficient level.

Method: To carry out phase 1, subroutine ARANK is called to rank scheduled plants for possible advancement. The list of ranked plants is returned to ADVANC in array IRANK. A two-part process is carried out to advance plants: (1) the year on-line (YRONSC) and, possibly, the beginning construction year (YRBGUN) are updated in the plant construction schedule (data group 23) and (2) the years in which system size is affected are determined. CUPDAT is called to update system size and the current capacity/demand differential (EXCESS).

To carry out Phase 2, the following steps are repeated until the capacity needs test is passed:

1. The plant construction technology k falling most short of its user-specified future mix is selected for scheduling. Technologies may be excluded from selection either by a nuclear moratorium or by a construction period that would extend beyond the current horizon year.
2. A type k plant is added to the unit inventory (data group 70) and to the plant construction schedule (data group 23).
3. The years in which system size are affected are determined. CUPDAT is called to update the current capacity/demand deficit.

5.4.2 Subroutine ARANK

Called by: ADVANC.

Calls: NUCSTG, NYDEFD.

Arguments:
KHRZ - Current horizon year beyond simulation year.
NADVBL - Number of scheduled plants that ARANK determines are advanceable.
ISTATE, IYEAR, ITRACE.

Task: Selects advanceable plants from construction schedule (data group 23) and ranks them for possible advancement.

Method: The construction schedule is scanned once. During the scan, plants are delineated for possible advancement if they meet four criteria: (1) the scheduled year on-line is greater than the current horizon year (KHRZ), (2) enough years remain to complete construction before KHRZ, (3) construction has not been deferred due to a nuclear moratorium, and (4) the plant is not one scheduled for oil-to-coal conversion.

Deferred plants (i.e., plants under construction) are ranked in the order of decreasing cost incurred to date. The remaining advanceable plants are ranked after deferred plants. If parts 1 or 2 of the three-part capacity needs test fail, base and intermediate plants are ranked before peak load plants. Otherwise, peakers are ranked first.

ARANK terminates with an error message when the number of deferred plants or the number of advanceable plants is greater than 300. (In the stand-alone version of PLAN, a call to subroutine ERROR writes an error message and halts execution.)

5.4.3 Subroutine CUPDAT

Called by: ADVANC, DEFER.

Arguments: I1, I2, I3, I4 - Define year ranges in which system size is affected by a scheduling adjustment.

SIZEMW - Size (MW) of scheduled plant.

IFLAG = 1, if CUPDAT is called as a result of plant addition.

= 2, if CUPDAT is called as a result of plant advancement.

= 3, if CUPDAT called as a result of construction deferral.

Task: Updates system size arrays (SYSIZE, AVALMW, AVAKWH) and current capacity/demand differentials (EXCESS) following plant construction schedule updates.

Method: Capacity arrays and excesses are updated as follows:

Advancements: SIZEMW is added to system size arrays between the horizon year (I1) and one year before the previous on-line year (I2). SIZEMW is subtracted beginning one year beyond the new retirement year (I3) and ending on the old retirement year (I4). Capacity/demand differentials are increased by SIZEMW.

Deferrals: System size arrays are decreased by SIZEMW between the previous on-line year (I1) and one year before the new on-line year (I2). SIZEMW is added beginning one year beyond the previous retirement year (I3) and ending on the new retirement year (I4). Capacity/demand differentials are decreased by SIZEMW.

Additions: System size arrays are increased by SIZEMW throughout the lifetime of the new plant. Capacity/demand differentials are increased by SIZEMW.

5.4.4 Subroutine DEFER

Called by: PLAN.

Calls: CUPDAT, DRANK.

Arguments: KHRZ - Current horizon year.

IYEAR, ISTATE, ITRACE.

Task: In order to supervise the deferral of plants scheduled for construction, DEFER is called when capacity exceeds demand in the current horizon year. A plant qualifies as a candidate for deferral if it is scheduled to be brought on-line in the current horizon year. Plants are selected for deferral until any portion of the three-part capacity needs test is passed by less than 2 percent.

Method: Upon entry to DEFER, subroutine DRANK is called to prepare a ranked list (IRANK) of deferrable plants. Deferral is carried out by application of the following steps to deferrable plants in their ranked order:

1. If deferral would cause any portion of the three-point test to be passed by less then 2 percent, stop; otherwise,
2. The year on-line (YRONSC) and, possibly, the year construction begins (YRBGUN) are updated in the plant construction schedule (data group 23).
3. The years in which system size are affected are determined. CUPDAT is called in order to update system size and current capacity/demand deficits.

5.4.5 Subroutine DRANK

Called by: DEFER.

Arguments: KHRZ - Current horizon year.

NDFRBL - Number of deferrable plants.

ISTATE, IYEAR, ITRACE.

Tasks: Delineates and ranks plants in the construction schedule for possible deferral.

Method: This routine picks out plants slated to come on-line in the current horizon year. Each one that is less than a user-prescribed percentage from completion is marked as a candidate for deferral and assigned a cost that represents the amount spent to date on construction. Candidates are then ranked in ascending order by costs incurred. Ranking occurs in array IRANK and is communicated to the calling routine (DEFER) in blank common. Plants are excluded from possible deferral if construction has progressed beyond a user-specified percentage or if the plant is one scheduled for oil-to-coal conversion.

DRANK terminates with an error message when the number of deferred plants is greater than 300. (In the stand-alone version of the PLAN, a call to subroutine ERROR writes a diagnostic message and halts execution.)

5.4.6 Subroutine NEWPLT

Called by: ADVANC, PLAN.

Arguments: ITECH - Construction technology code of plant added to the unit inventory (data group 70).

ISTATE.

Task: Fills in default properties of plants added to the unit inventory.

5.4.7 Subroutine NEWSCH

Called by: ADVANCE, DEFER, PLAN.

Arguments: IYEAR, ISTATE.

KHRZ - Current horizon year.

Mode = 1, if plant existed in initial unit inventory.

= 2, if plant has been added during simulation.

Task: Fills in default values of plants added to the construction schedule (data group 23).

5.4.8 Function NUCSTG

Called by: ARANK, UPSCHD.

Task: Determines the stage of construction that a nuclear plant must have reached if construction can be completed before the new nuclear year.

5.4.9 Function NYDEFD

Called by: ARANK, UPSCHD.

Argument: IYEAR.

Task: Determines the deferral state of a plant under construction. This function is set to:

0, if construction has begun and plant is not in deferral state.

-1, if construction has not yet begun.

+N, if construction has been in a deferral state for N years.

5.4.10. Subroutine PLAN

Called by: Control Program.

Calls: ADVANC, DEFER, POLPEN, UPSCHD, NEWSCH, TDGNA.

Arguments: ISTATE, IYEAR, ITRACE.

Tasks: Supervisory routine for the capacity planning module. PLAN's tasks fall into three categories:

1. National level (performed once in simulation):

   –Get national data from data group 20.

2. State-level (performed each time that processing for a new state begins):

   –Carry out initial read of unit inventory (data group 70) in order to set up construction schedule (data group 23) and to initialize system size arrays (data group 24).

3. Yearly (performed on each call):

   –Update construction schedule (call UPSCHD) to reflect passage of time.

   –Get current building fractions (data group 25).

   –Get 15-year demand projections (data group 14).

   –Update capacity arrays with pollution penalties (call POLPEN).

   –Carry out scheduling algorithm through look-ahead horizon.

   –Calculate capital costs (call TDGNA).

Method: Data from each plant are accessed during the initial processing of the unit inventory. For announced plants, two actions occur. First, the year on-line is changed to the value 9999 and put back to data group 70. Second, an entry is made in the construction schedule for the plant. Subroutine NEWSCH is called to set data items for new entries to the construction schedule. Also, during the initial unit inventory processing, the three system size arrays (SYSIZE, AVAKWH, and AVALMW) are initialized to reflect the contribution that each plant makes during its lifetime to the total capacity of the current state.

The scheduling algorithm is carried out over a look-ahead horizon that extends 11 years beyond the current simulation year. Prior to each yearly iteration, the initial capacity/demand differences corresponding to the three parts of the capacity needs test are stored in array EXCESS(3). If all three parts of the test are passed [EXCESS(I=1,3) ≥0], then subroutine DEFER is called in order to reduce projected system size by deferring plant construction. Otherwise, ADVANC is called to increase projected system size by advancing construction on scheduled plants or by adding plants to the construction schedule.

5.4.11 Subroutine POLPEN

Called by: PLAN.

Arguments: ISTATE, IYEAR, ITRACE.

TOTPEN - Accumulation of capacity penalties in current year.

Task: Modifies capacity outlook based upon allowances made for pollution control devices added to existing plants.

Method: This routine scans the three pollution control device construction schedules (data groups 32, 33, and 34) for plants retrofitted in the current year. For each such plant, the capacity outlook arrays (data group 24) are updated to reflect reduced system capacity for the remaining plant life.

5.4.12 Subroutine TDGNA

Called by: PLAN.

Arguments: ISTATE, IYEAR, ITRACE.

Task: Computes yearly construction expenditures for transmission, distribution, and general plant administration.

Method:

1. The construction expenditure for transmission (CONEXT) is obtained by multiplying the increase in maximum peak load to date (PEAKD - PEAKMX) by the capital cost for transmission (21,CCTRAN). CONEXT is set to zero in simulation year 1 and in years in which there is no increase in peak load to date (PEAKD - PEAKMX <0).

2. Construction expenditures for distribution (CONEXD) are the product of the increase in net generation since the previous peak year (GENET - GENETL) and the capital

cost for distribution (21,CCDIST). Construction expenditures for general administration (CONEXO) are the product of the increase in net generation and the capital cost for operations and maintenance (21,CCGNA). CONEXT and CONEXO are set to zero in year 1 and in years in which there is no increase in net generation since the previous peak year (GENET - GENETL <0).

5.4.13 Subroutine UPSCHD

Called by: PLAN.

Arguments: IYEAR, ISTATE, ITRACE.

TOTPEN - Accumulation of current year's capacity penalties.

Calls: NUCSTG.

Tasks: PLAN calls UPSCHD each year to perform the following tasks in preparation for further scheduling adjustments:

1. Update entries in construction schedule (data group 23) to reflect passage of one year.
2. Update unit inventory (data group 70) for plants coming on-line in current year.
3. Write capacity added report data (report 205).
4. Update capacity outlook array to reflect pollution penalties placed on newly constructed plants.

Method: The central control flow of UPSCHD enables a complete scan of the plant construction schedule. As each unit is processed, the corresponding construction schedule entry is modified (and, possibly, other tasks are performed), subject to which of four cases applies:

1. Case 1. *Plant is coming on-line in the current year.*

   - Set the plant stage (STAGE) and the percentage of costs incurred in the current year (PCT) to zero.

   - Reset on-line year and retirement year in the unit inventory (data group 70).

   - Accumulate data for capacity added report.

   - Reduce system size arrays by capacity penalty, if the newly constructed plant has a pollution control device.

2. Case 2. *Construction is beginning in current year.* Set STAGE to 1 and set PCT based on construction cost spread date (SPREAD). For plants undergoing oil-to-coal conversion, STAGE is set to 1 and PCT is set to 1.0.

3. Case 3. *Construction has not yet begun.* STAGE and PCT remain at zero.

4. Case 4. *Construction has begun.*

   - Case 4a. *Construction has been deferred due to a nuclear moratorium.* PCT is set to zero and scheduled year on-line (YRONSC) is set beyond "end nuclear moratorium" year (NEWNUC).

   - Case 4b. *Construction is continuing on schedule.* PCT is set to zero.

5.5 Flowcharts of Principal Subroutines

Flowcharts of seven of the principal capacity planning subroutines are found in Figures C5-3 through C5-9.

Figure C5-3
SUBROUTINE ADVANC

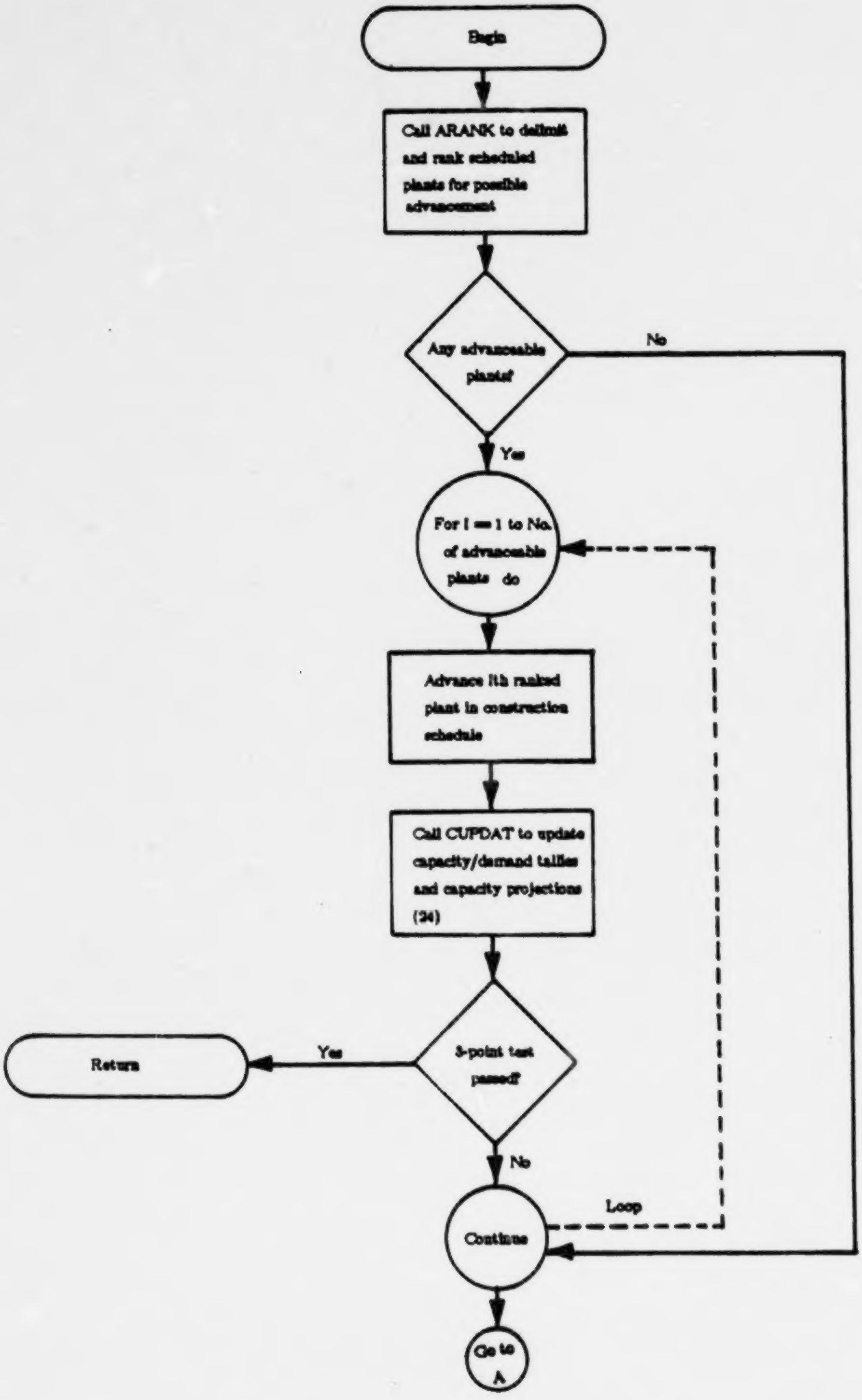

Begin
Call ARANK to delimit and rank scheduled plants for possible advancement
Any advanceable plants?
No
Yes
For I = 1 to No. of advanceable plants do
Advance Ith ranked plant in construction schedule
Call CUPDAT to update capacity/demand tallies and capacity projections (24)
3-point test passed?
Yes
Return
No
Loop
Continue
Go to A

Figure C5–3 (contd.)

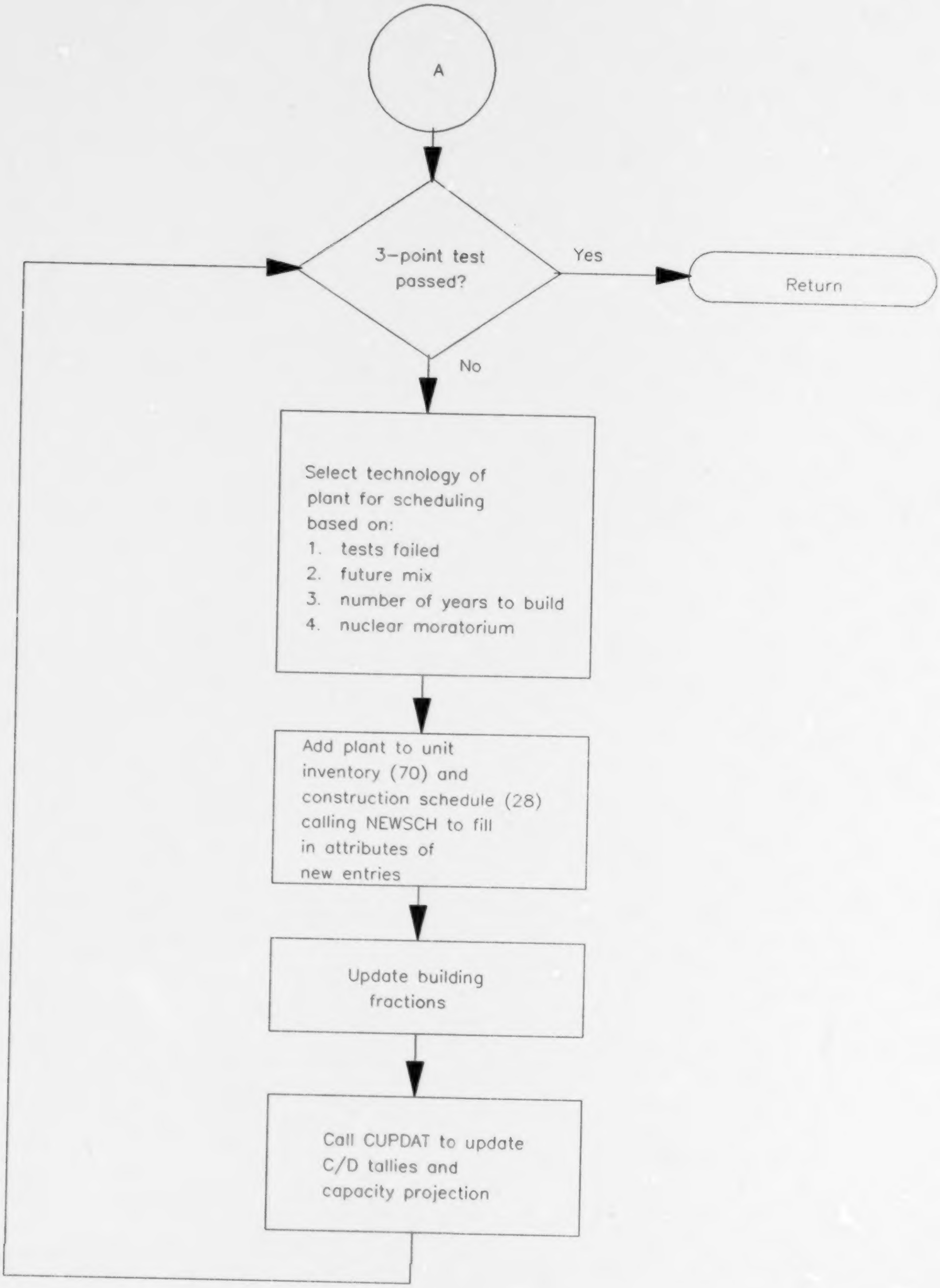

A
3–point test passed?
Yes
Return
No
Select technology of plant for scheduling based on:
1. tests failed
2. future mix
3. number of years to build
4. nuclear moratorium
Add plant to unit inventory (70) and construction schedule (28) calling NEWSCH to fill in attributes of new entries
Update building fractions
Call CUPDAT to update C/D tallies and capacity projection

Figure C5–4
SUBROUTINE ARANK

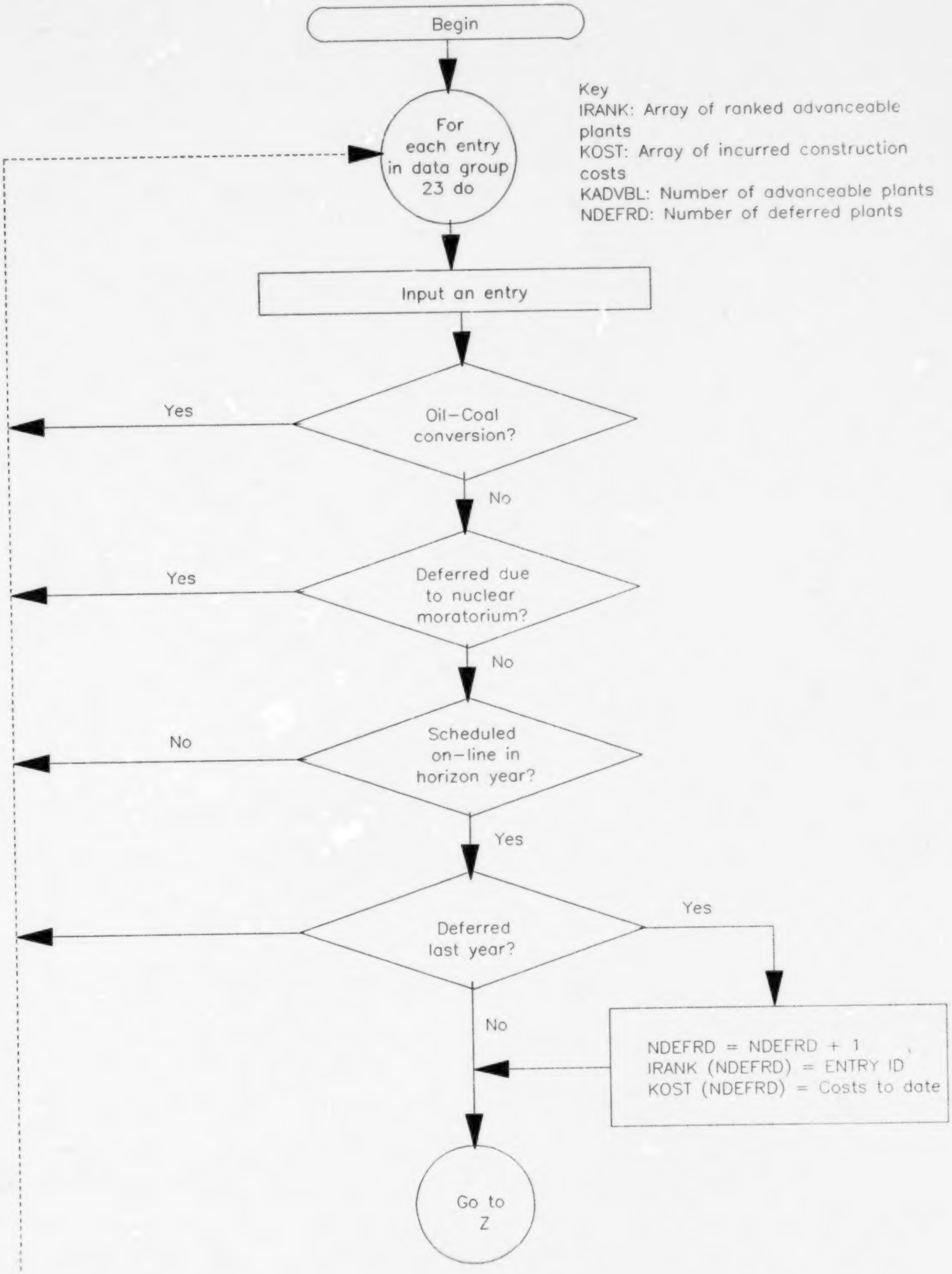

Begin
For each entry in data group 23 do
Key
IRANK: Array of ranked advanceable plants
KOST: Array of incurred construction costs
KADVBL: Number of advanceable plants
NDEFRD: Number of deferred plants
Input an entry
Yes
Oil–Coal conversion?
No
Yes
Deferred due to nuclear moratorium?
No
No
Scheduled on–line in horizon year?
Yes
Deferred last year?
Yes
No
NDEFRD = NDEFRD + 1
IRANK (NDEFRD) = ENTRY ID
KOST (NDEFRD) = Costs to date
Go to Z

Figure C5–4 (contd.)

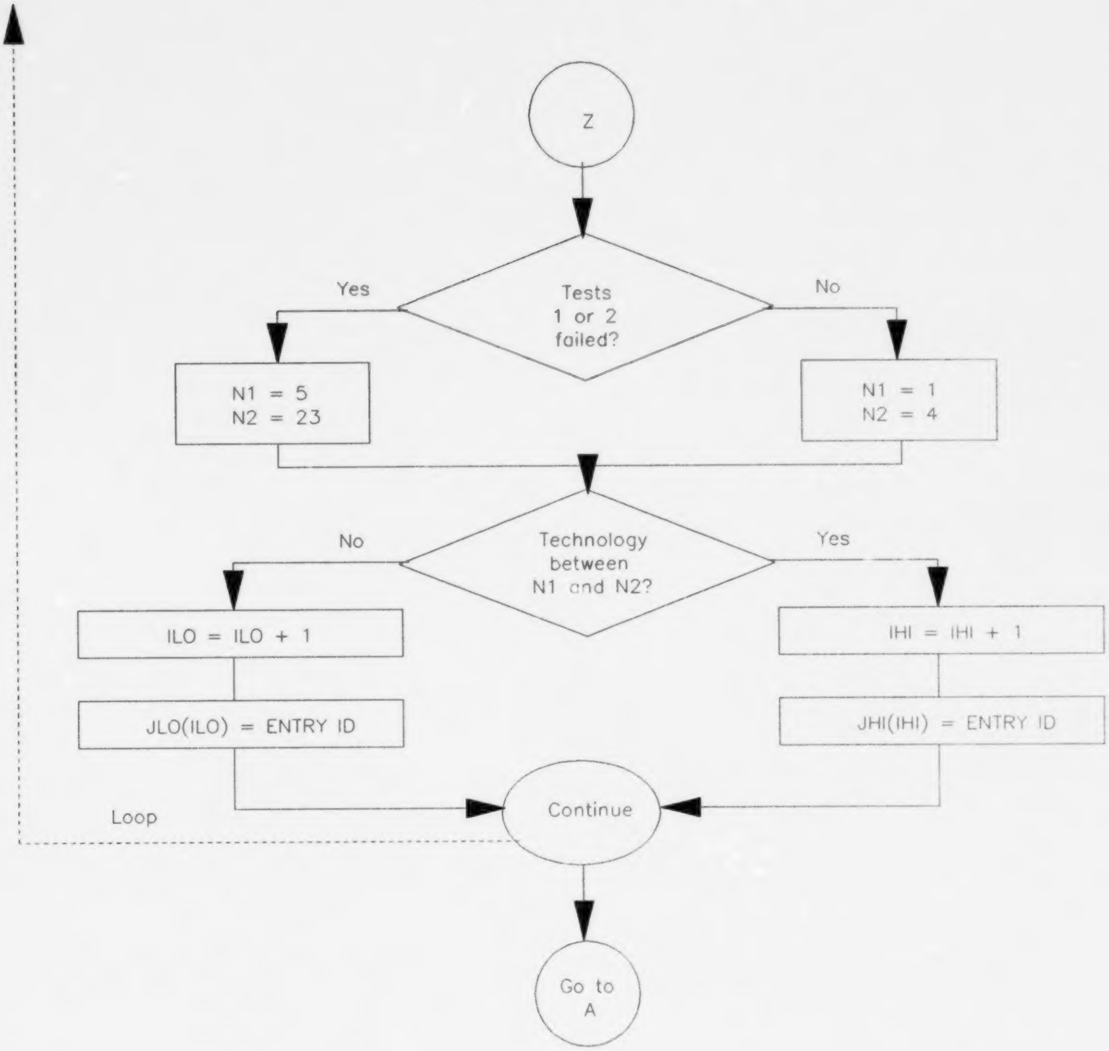


Figure C5–4 (contd.)

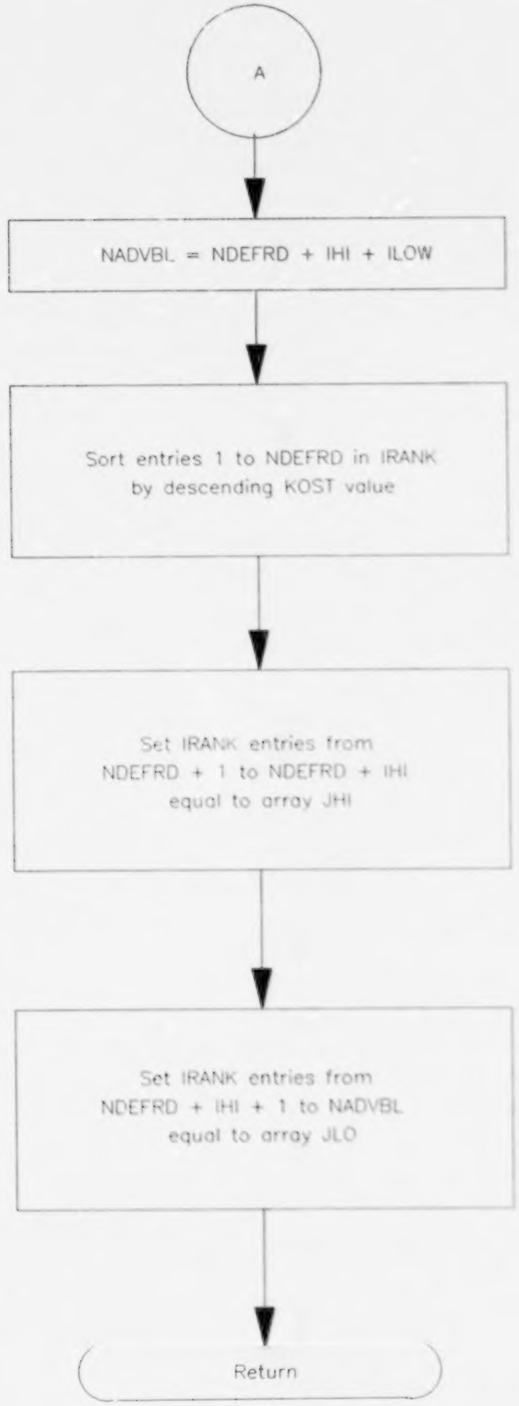

A
NADVBL = NDEFRD + IHI + ILOW
Sort entries 1 to NDEFRD in IRANK by descending KOST value
Set IRANK entries from NDEFRD + 1 to NDEFRD + IHI equal to array JHI
Set IRANK entries from NDEFRD + IHI + 1 to NADVBL equal to array JLO
Return

Figure C5–5
SUBROUTINE DEFER

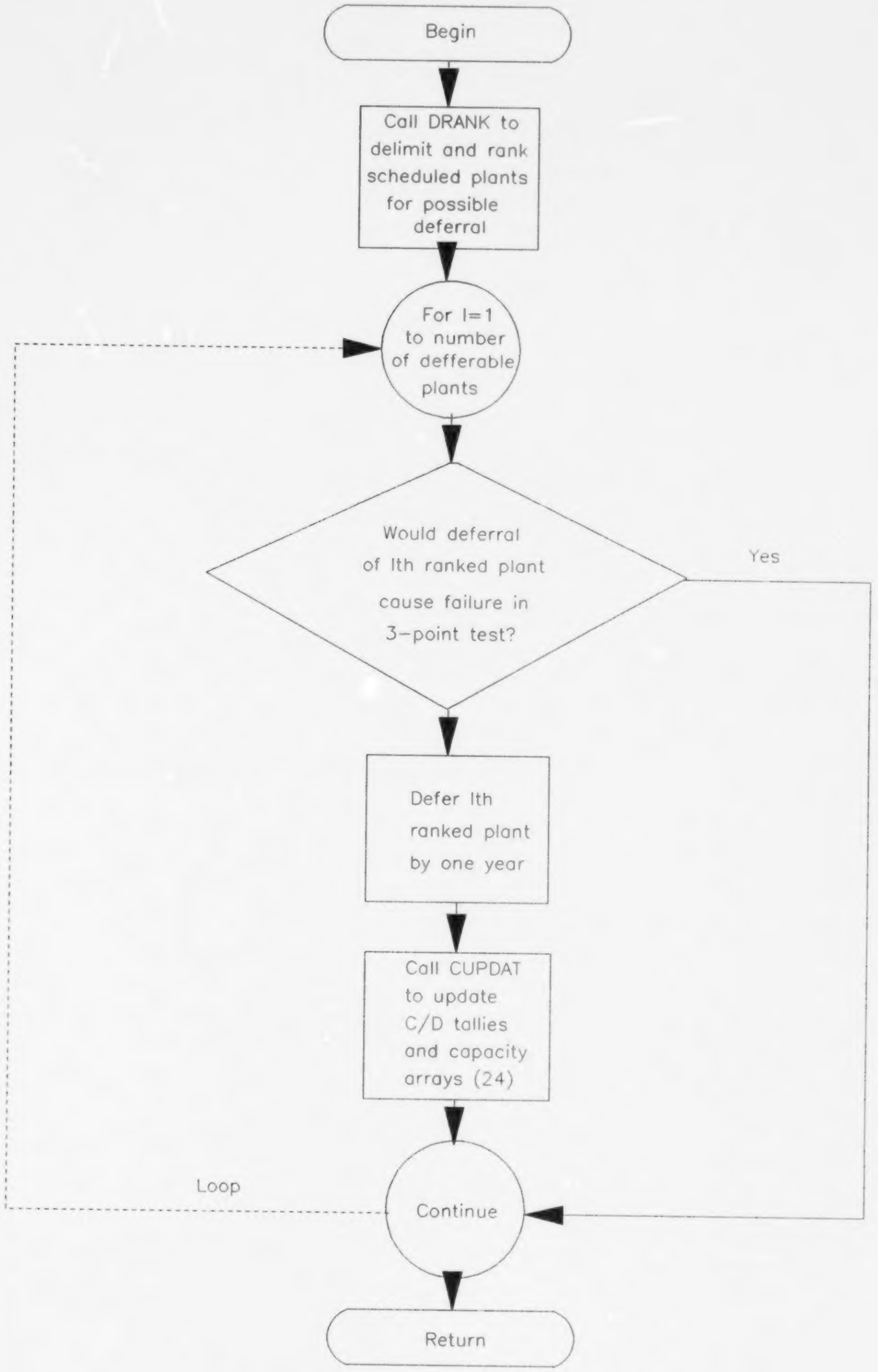

Begin
Call DRANK to delimit and rank scheduled plants for possible deferral
For I=1 to number of defferable plants
Would deferral of Ith ranked plant cause failure in 3–point test?
Yes
Defer Ith ranked plant by one year
Call CUPDAT to update C/D tallies and capacity arrays (24)
Loop
Continue
Return

Figure C5–6
SUBROUTINE DRANK

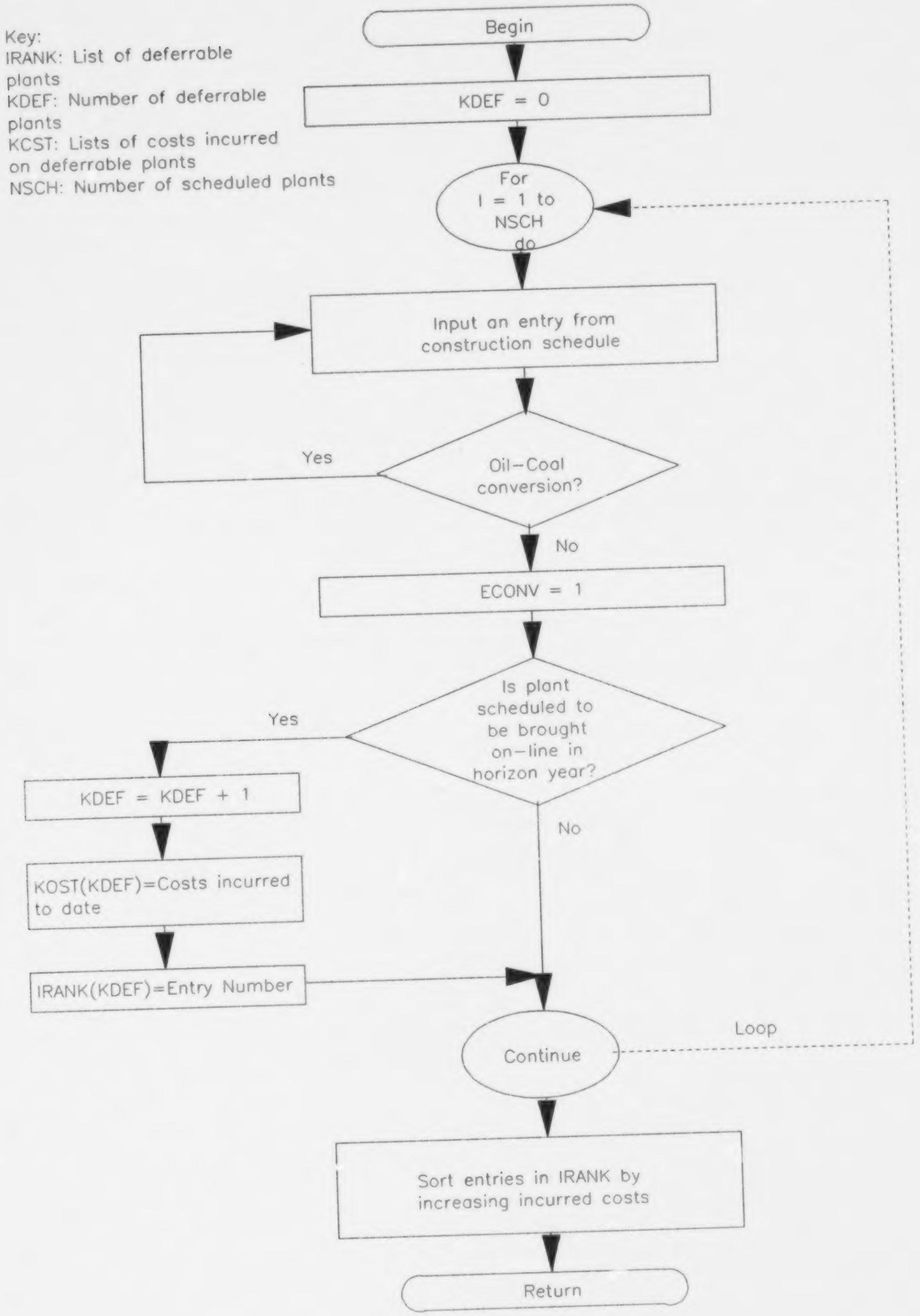

Key:
IRANK: List of deferrable plants
KDEF: Number of deferrable plants
KCST: Lists of costs incurred on deferrable plants
NSCH: Number of scheduled plants
Begin
KDEF = 0
For I = 1 to NSCH do
Input an entry from construction schedule
Oil–Coal conversion?
Yes
No
ECONV = 1
Is plant scheduled to be brought on–line in horizon year?
Yes
No
KDEF = KDEF + 1
KOST(KDEF)=Costs incurred to date
IRANK(KDEF)=Entry Number
Continue
Loop
Sort entries in IRANK by increasing incurred costs
Return

Figure C5–7
SUBROUTINE PLAN

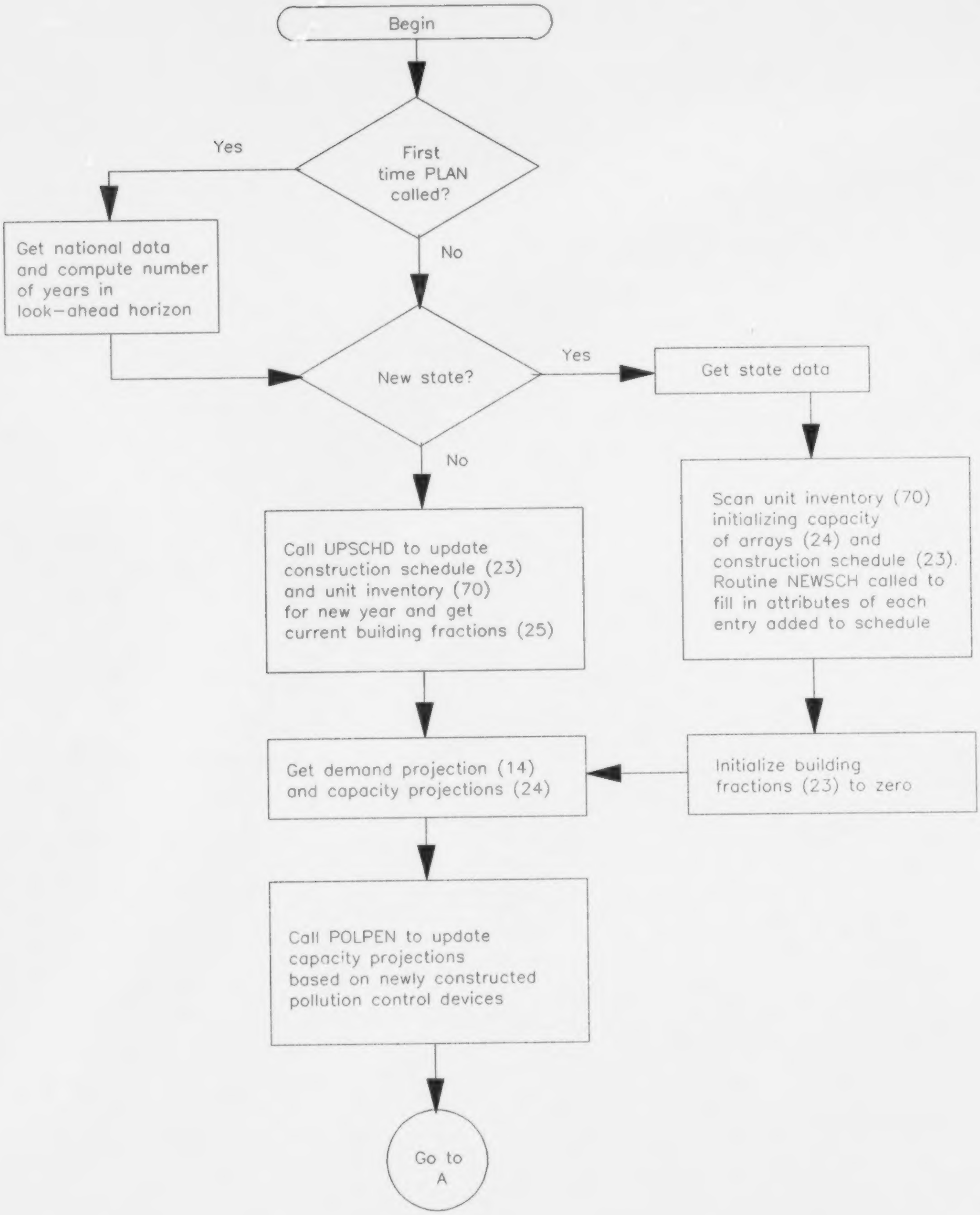

Begin
First time PLAN called?
Yes
No
Get national data and compute number of years in look–ahead horizon
New state?
Yes
No
Get state data
Scan unit inventory (70) initializing capacity of arrays (24) and construction schedule (23). Routine NEWSCH called to fill in attributes of each entry added to schedule
Call UPSCHD to update construction schedule (23) and unit inventory (70) for new year and get current building fractions (25)
Get demand projection (14) and capacity projections (24)
Initialize building fractions (23) to zero
Call POLPEN to update capacity projections based on newly constructed pollution control devices
Go to A

Figure C5–7 (contd.)

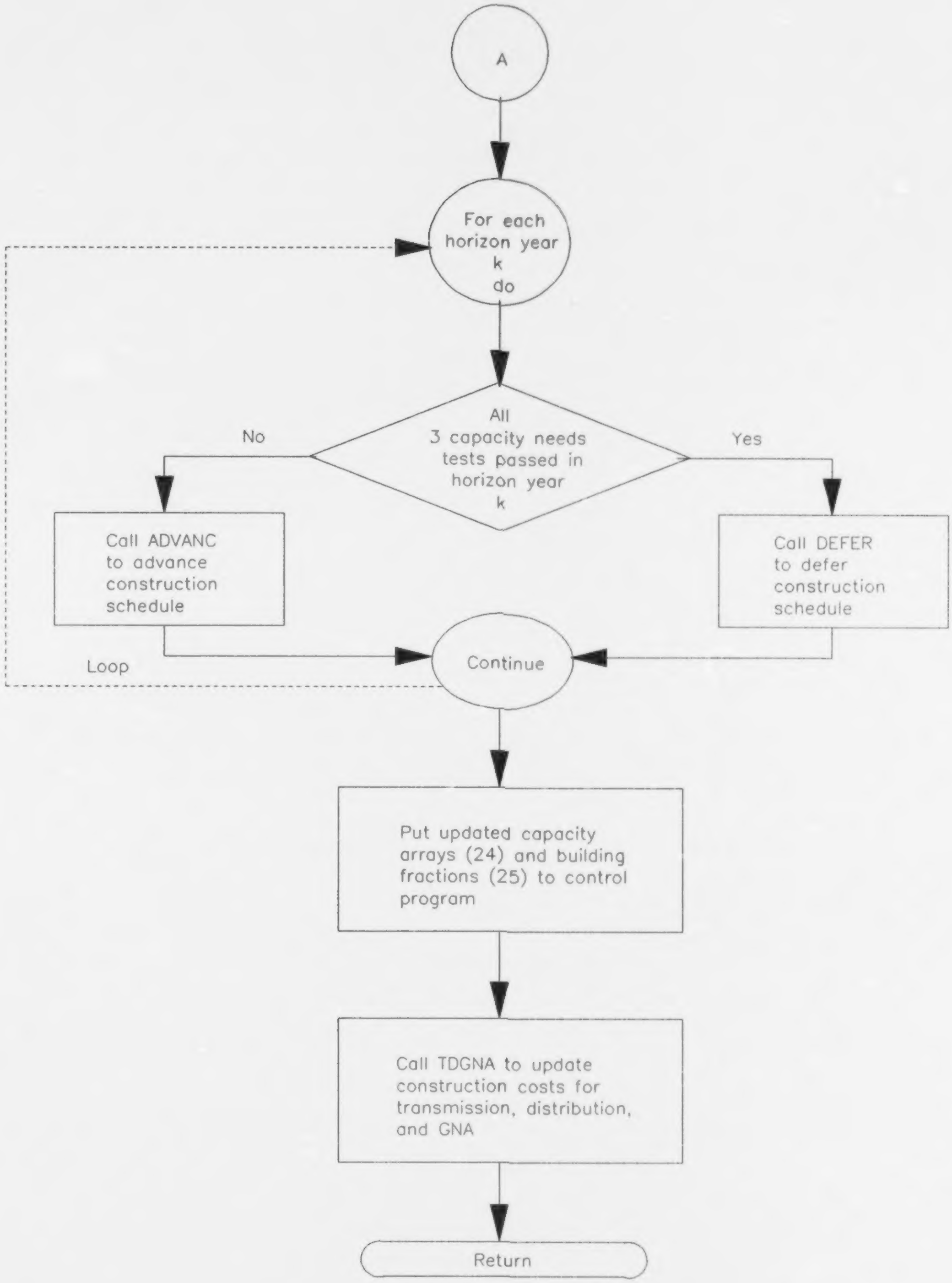
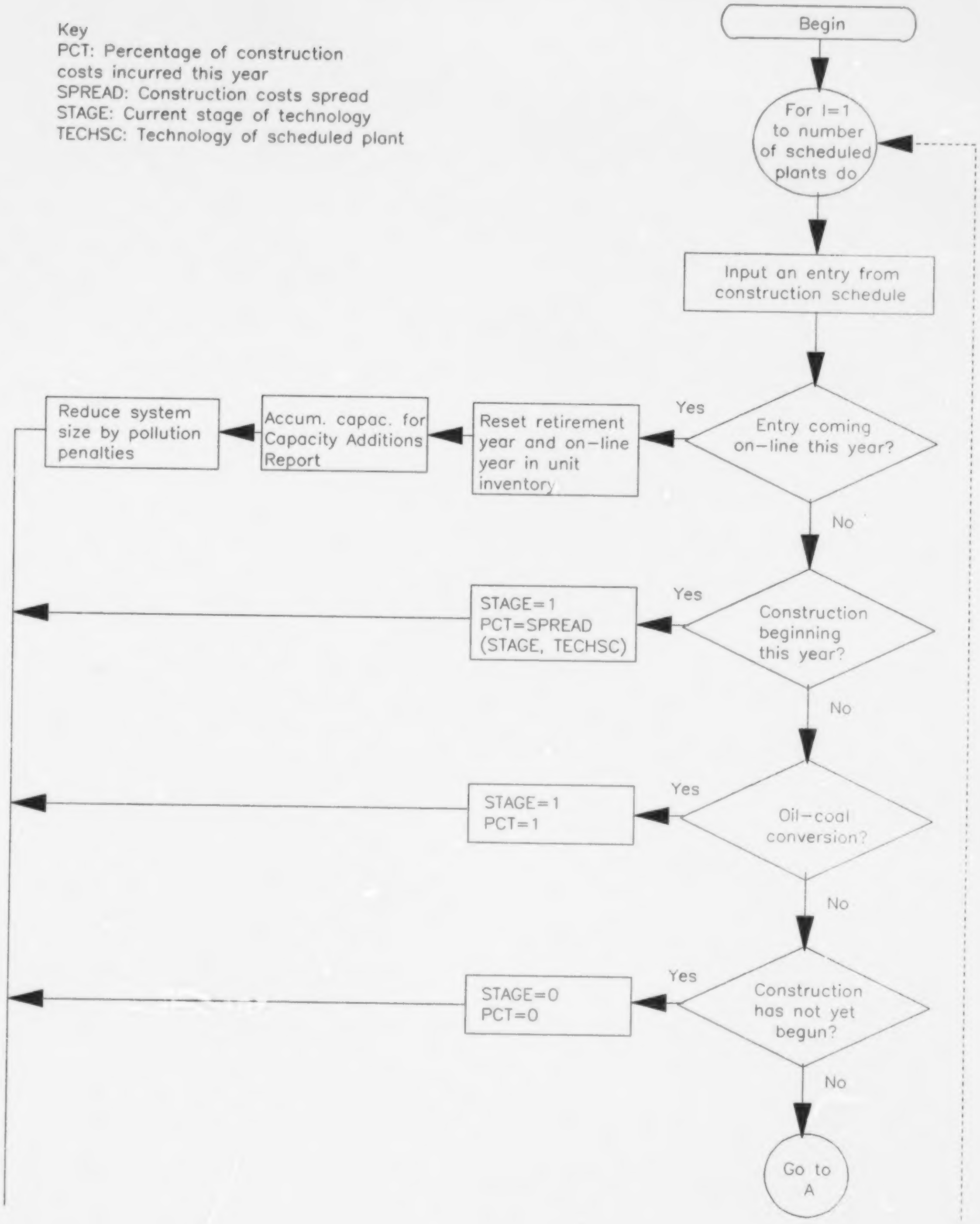

A
For each horizon year k do
All 3 capacity needs tests passed in horizon year k
No
Yes
Call ADVANC to advance construction schedule
Call DEFER to defer construction schedule
Loop
Continue
Put updated capacity arrays (24) and building fractions (25) to control program
Call TDGNA to update construction costs for transmission, distribution, and GNA
Return

Figure C5–8
SUBROUTINE UPSCHD



Key
PCT: Percentage of construction costs incurred this year
SPREAD: Construction costs spread
STAGE: Current stage of technology
TECHSC: Technology of scheduled plant

Begin
For I=1 to number of scheduled plants do
Input an entry from construction schedule
Entry coming on–line this year?
Yes
No
Reset retirement year and on–line year in unit inventory
Accum. capac. for Capacity Additions Report
Reduce system size by pollution penalties
Construction beginning this year?
Yes
No
STAGE=1
PCT=SPREAD (STAGE, TECHSC)
Oil–coal conversion?
Yes
No
STAGE=1
PCT=1
Construction has not yet begun?
Yes
No
STAGE=0
PCT=0
Go to A

Figure C5–8 (contd.)

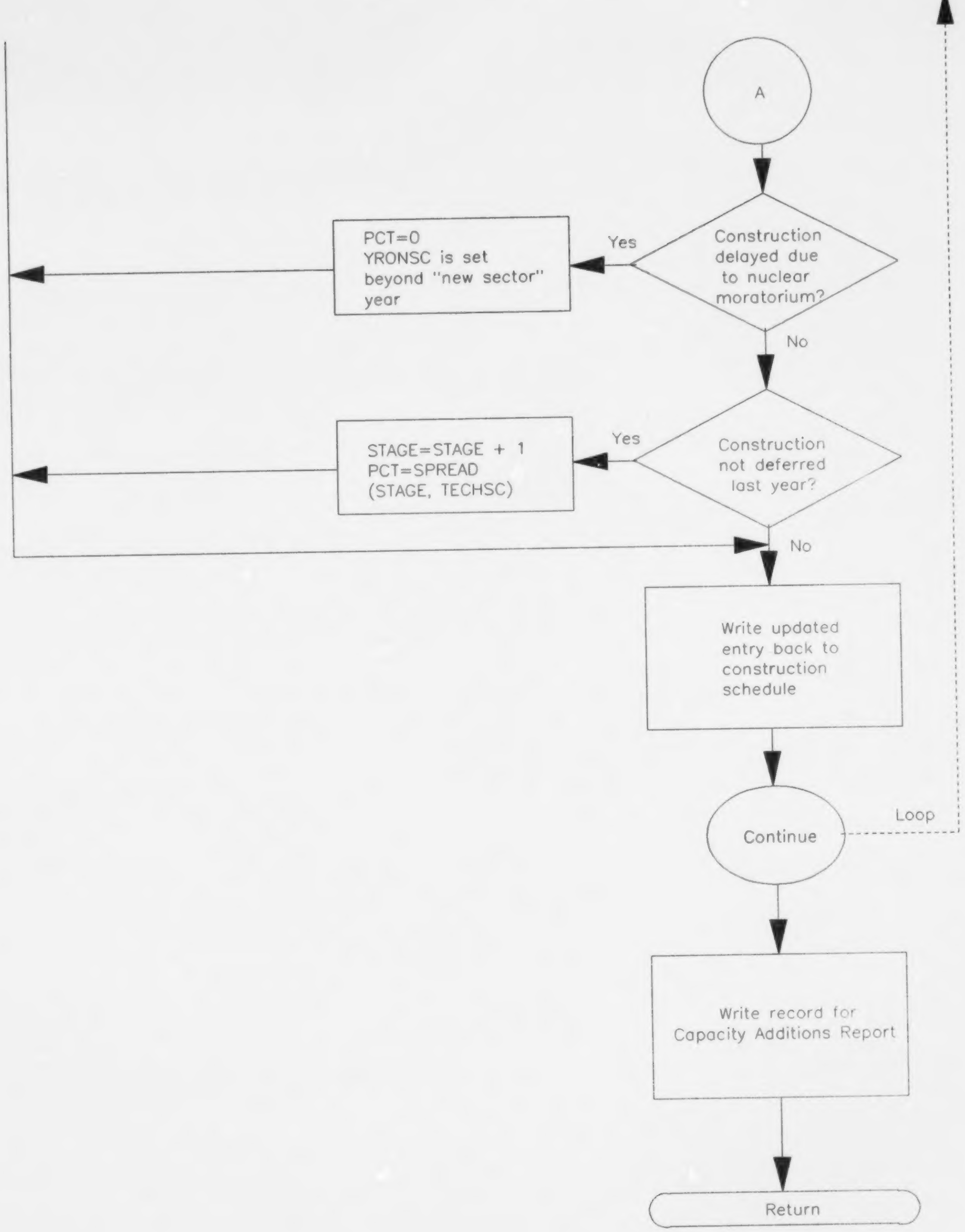
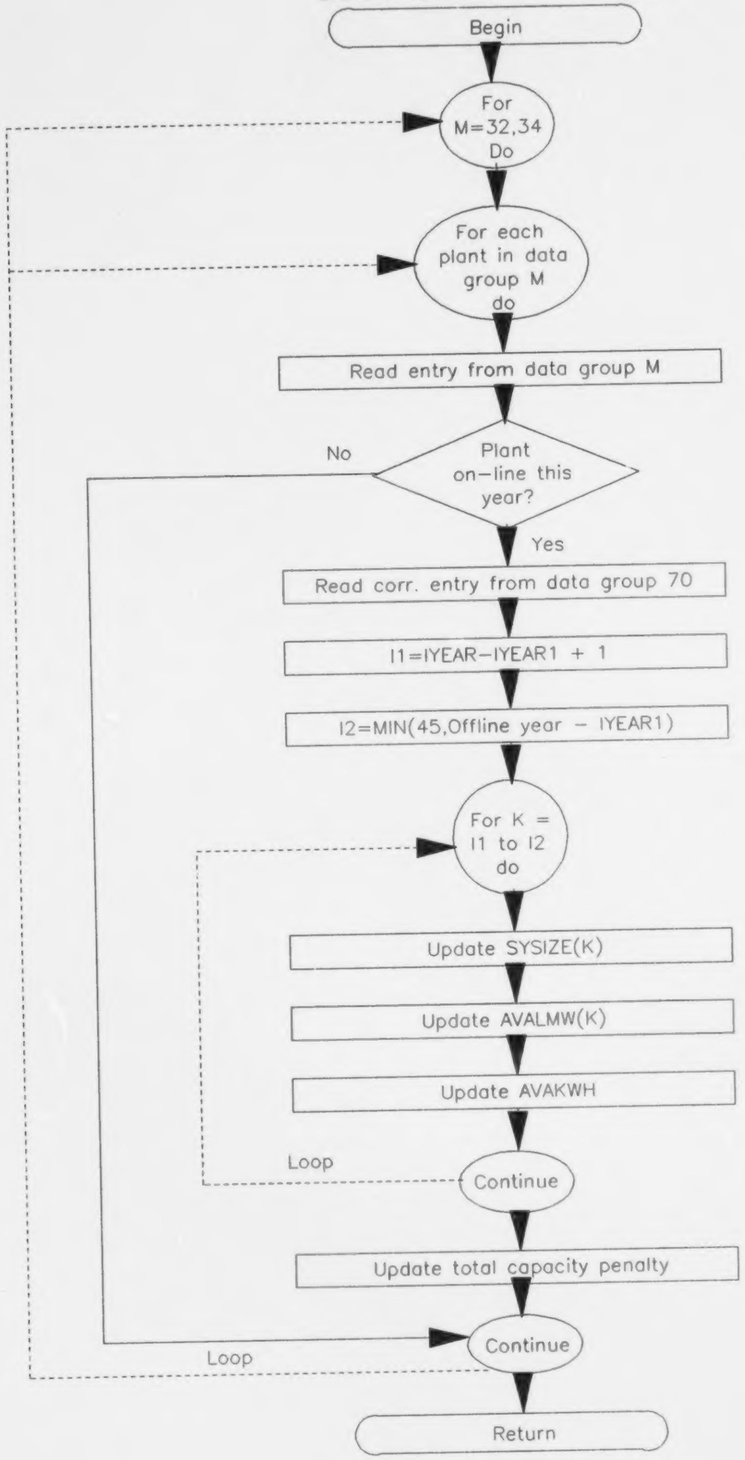

A
Construction delayed due to nuclear moratorium?
Yes
PCT=0
YRONSC is set beyond "new sector" year
No
Construction not deferred last year?
Yes
STAGE=STAGE + 1
PCT=SPREAD (STAGE, TECHSC)
No
Write updated entry back to construction schedule
Continue
Loop
Write record for Capacity Additions Report
Return

Figure C5–9
SUBROUTINE POLPEN



5.6. Variable Definitions

Table C5-2 gives short descriptions of the variables used in the capacity planning module, while Table C5-3 gives detailed information about these variables.

REFERENCES

1. Caroline J. Badger and Howard Ojalvo. **"Advanced Utility Simulation Model, Documentation of System Design, State Level Model (Version 1.0)."** U.S. Environmental Protection Agency. EPA-600/8-88-071c (NTIS PB89-101208). August 1988.

Table C5-2
VARIABLE DESCRIPTIONS

Variable	Unit	Description
ACTRES	Fraction	Actual reserve margin
ADDCOAL	MW	Capacity added, coal
ADDHYD	MW	Capacity added, hyroelectric
ADDNUC	MW	Capacity added, nuclear
ADDOTH	MW	Capacity added, "other"
ADPEAK	MW	Scheduled peak capacity
ADTECH	MW	Capacity additions to construction schedule by plant construction technology
ADTOTL	MW	Total scheduled capacity
ADTYPE	MW	Capacity additions by technology code
AVAIL	Fraction	Availabilities by construction technology
AVAILU	Fraction	Availability of an entry in unit inventory
AVAKWH	KWh	Available kilowatt hours over 45 years
AVALMW	MW	Available megawatts over 45 years
BDYR	Year	Year before which no plant may be scheduled or advanced
BLDCST	$/KW	Building costs by construction technology
BLDFRC	MW	Array for accessing data group 25
BLDYR		Number of years to build plants of each plant construction technology
BOILER	Codelist G	Boiler bottom type
BPOLD	Year	Plants with on-line year less than BPOLD may not be deferred
CAPADD	MW	Total capacity added, current year
CAPCUR	MW	Current capacity
CAPINT	MW	Initial capacity
CAPPEN	MW	Capacity penalty for a scheduled plant

Table C5-2 (contd.)

Variable	Unit	Description
CAPPNR	MW	Capacity penalty for an existing plant
CCDIST	$/KWh	Transmission capital cost
CCGNA	$/KWh	Capital cost for general plant administration
CCTRAN	$/KW	Distribution capital cost
CFCUR	Fraction	Current capacity factor
CFDES	Fraction	Design capacity factor
CFMAX	Fraction	Maximum capacity factor by technology
CFSCH	Fraction	Capacity factor of a scheduled plant
CONEXD	Million $	Construction expenditures for distribution
CONEXO	Million $	Construction expenditures for general plant and intangibles
CONEXT	Million $	Construction expenditures for transmission
CONV	1 = yes 2 = no	Oil-to-coal conversion flag
CWP	Million $	Accumulated direct construction cost afudc
DEFICT	Fraction	Amount by which scheduled capacity of a specific technology falls below user specification
DEFRAC	Fraction	Construction deferral fraction
EXCESS	MW KWh MW	Amount by which capacity exceeds demand for each of the three parts of the capacity needs test
FIPLOC	Codelist I	FIPS location code of entry in unit inventory
FIRTYP	Codelist H	Plant firing type of entry in unit inventory
FRACT	MW	Scheduled peak capacity as a fraction of total scheduled capacity
FRCBLT	Fraction	Fraction of completion for a plant under construction
GEN	GWh	Generation, current year

Table C5-2 (contd.)

Variable	Unit	Description
GENET	Billion KWh	Generation, net of transfers (current year)
GENETL	Billion KWh	Last year's generation, net of transfers
GENSC	MW	Size of scheduled plant
HEATR8	Btu/KWh	Heat rate of plant in unit inventory
HR8NEW	Btu/KWh	Heat rate by construction technology
HR8SCH	Btu/KWh	Heat rate of scheduled plant
IBDYR	Constant	Constant for accessing BDYR via GETSCN call (default = 65)
IBPOLD	Constant	Constant for accessing BPOLD via GETSCN call (default = 64)
ICONV		Temporary variable; used to compute CONV in UPSCHD
IRANK		List of advanceable or deferrable plants; also used as a buffer for writing
ISTATE	Codelist I	State FIPS code
ITECH	Codelist B	Plant construction technology
ITRACE		Trace level
IYEAR	Year	Current year
IYEAR1	Year	First year of simulation
KDEF		Count of deferrable plants
KHRZ		Current horizon year
KOST	$	Construction costs incurred on plants ranked for deferral or advancement; also used as buffer for writing
LSTSTA	Codelist I	Contains previous value of ISTATE; used to test for change in ISTATE
MIXOFF		Location of future mix variables in scenario file

Table C5-2 (contd.)

Variable	Unit	Description
NADVBL		Number of advanceable plants
NDEF		Number of years a plant has been deferred
NDEFRD		Number of deferred plants
NDFRBL		Number of deferrable plants
NEWNUC		Location in scenario parameter file of the first year after nuclear moratorium has ended
NHORIZ		Number of horizon years
NOXDV	Codelist F	NOx device code
NPLT		Number of entries in unit inventory
NRETRO		Number of entries in any of the three retrofit schedules (data groups 32, 33, and 34)
NSCH		Number of entries in the plant construction schedule
NSCHLD		Number of units added to the plant construction schedule
NUCFRC		Location in the scenario parameter of "the fraction of completion that a nuclear plant must have attained if construction is not deferred until after a nuclear moratorium"
NUCTEK	Codelist B	Technology code of nuclear plants
OANDM	Mills/KWh	Nonfuel O&M costs of entry in unit inventory
OMNEW	Mills/KWh	Nonfuel O&M costs by plant construction technology
PCT	Percent	Percent of costs incurred in current stage of plant construction
PEAKD	MW	Peak demand in current year
PEAKMX	MW	Maximum peak demand to date
PKADD	MW	Capacity added, peak plants

Table C5-2 (contd.)

Variable	Unit	Description
PKFRAC	Fraction	Scheduled peak capacity as fraction of total scheduled capacity
PRIME	Codelist A	Prime mover type of entry in unit inventory
PRIMSC	Codelist A	Prime mover type of entry in construction schedule
PRJPLD	MW	Projected peak load over 15-year horizon
PRJQEL	Billion KWh	Projected quantity of electricity over 15-year horizon
PTYPE	Codelist B	Prime mover type by plant construction technology
RETIRE	Year	Retirement year of plant in unit inventory
SEQNO		Entry number of plant in unit inventory
SIZEMW	MW	Capacity of new or updated entry in plant construction schedule
SIZNEW	MW	Plant capacity by construction technology
SOXDV	Codelist E	SOx control technology code for scheduled plant
SPREAD	Fraction	Cost spread by plant construction technology
STAGE		Construction stage (or year) of a scheduled plant
SYSIZE	MW	System size over 45 years
TCCNOX	Million $	Total construction cost for NOx unit
TCCPLT	Million $	Total construction cost for SOx unit
TCCSOX	Million $	Total construction cost for TSP unit
TECH	Codelist B	Plant construction technology of unit inventory entry
TECHSC	Codelist B	Plant construction technology of scheduled entry
TOTITC	Million $	Accumulated investment tax credit

Table C5-2 (contd.)

Variable	Unit	Description
TOTPEN	MW	Total capacity penalty in current year
TOTSCH	MW	Total scheduled capacity minus scheduled capacity brought on-line
TSPDV	Codelist D	TSP device code for scheduled plant
TVCPC	$/year	Total variable cost of all devices for scheduled plant
USER		User-specified construction schedule flag
UNITNO	Hollerith string	Unit identification of unit inventory entry
UNITR		Entry number of a plant in a pollution control retrofit schedule
UNITSC		Entry number of a scheduled unit
VCAP		Access array for data group 24
VDEM		Access array for data group 14
VDEM		Access array for data group 15
VEST	Million $	Accumulated direct construction cost of scheduled plant
VNATL		Access array for data group 20
VRETRO		Access array for data groups 32, 33, and 34
VSTATE		Access array for data group 21
VTDGNA		Access array for data group 22
VUNIT		Access array for data group 70
XMULT		Multiplier (share owned) for entry in unit inventory
XPDLIF		Expected life a new plant by construction technology
YEARON		Scheduled year on-line
YRBGUN		Scheduled first year of plant construction

Table C5-2 (contd.)

Variable	Unit	Description
YROFF	Year	Year after a plant retires
YRONSC	Year	Scheduled initial on-line year

Table C5-3
PLAN VARIABLE INFORMATION

Variable	Type	Dimension	Unit	Storage Location	Accessed from	Used by
ACTRES	Real		Fraction			PLAN
ADDCOAL	Real		MW			UPSCHD
ADDHYD	Real		MW			UPSCHD
ADDNUC	Real		MW			UPSCHD
ADDOTH	Real		MW			UPSCHD
ADPEAK	Real		MW	//		UPSCHD, PLAN
ADTECH	Real	23	MW	//[a]	DG 24	ADVANC
ADTOTL	Real		MW	//	DG 24	ADVANC, PLAN
ADTYPE	Real	23	MW	//		UPSCHD, PLAN
AVAIL	Real	23	Fraction	/PLNMTL/	DG 20	CUPDAT, DEFER, NEWPLT, PLAN
AVAILO	Real		Fraction	//	DG 70	NEWPLT, PLAN, POLPEN, UPSCHD
AVAKWH	Real	45	KWh	//	DG 24	CUPDAT, PLAN, POLPEN, UPSCHD
AVALMW	Real	45	MW	//	DG 24	CUPDAT, PLAN, POLPEN, UPSCHD
BDYR	Real		Year		GETSCN(65)	ADVANC, ARANK
BLDCST	Real	23	$/KW	/PLNATL/	DG 20	ARANK, DRANK, NEWSCH, PLAN
BLDFRC	Real	24	MW	//	DG 25	PLAN
BLDYR	Real	23		/PLNMTL/	DG 20	ADVANC, ARANK, NEWSCH, PLAN
BOILER	Real		Codelist G	//	DG 70	NEWPLT
BFOLD	Real		Year		GETSCN(64)	DRANK
CADADD	Real		MW			UPSCHD, PLAN

Table C5-3 (contd.)

Variable	Type	Dimension	Unit	Storage Location	Accessed from	Used by
CAPCUR	Real		MW	//	DG 70	NEWPLT
CAPINT	Real		MW	//	DG 70	NEWPLT, NEWSCH, PLAN, UPSCHD
CAPPEN	Real		MW	//	DG 23	NEWSCH, UPSCHD
CAPPNR	Real		MW	//	DG 32,33,34	POLPEN
CAPSC	Real		MW	//	DG 23	ADVANC, DEFER, NEWSCH
CCDIST	Real		$/KWh	/PLNSTA/	DG 21	TDGNA
CCGNA	Real		$/KWh	/PLNSTA/	DG 21	TDGNA
CCTRAN	Real		$/KWh	/PLNSTA/	DG 21	TDGNA
CFCUR	Real		Fraction	//	DG 70	NEWPLT
CFDES	Real		Fraction	//	DG 70	NEWPLT, NEWSCH
CFMAX	Real	23	Fraction	//	DG 23	CUPDAT, DEFER, NEWPLT, PLAN, POLPEN, UPSCHD
CFSCH	Real		Fraction	//	DG 23	NEWSCH
CONEXD	Real		Million $		DG 22	TDGNA
CONEXO	Real		Million $		DG 22	TDGNA
CONEXT	Real		Million $		DG 22	TDGNA
CONV	Real			//	DG 23	ARANK, DRANK, UPSCHD
CWP	Real		Million $	//	DG 23	NEWSCH
DEFICT	Real		Fraction			ADVANC
DEFRAC	Real		Fraction		GETSCN(63)	DRANK
EXCESS	Real	3	MW KWh	//		ADVANC, ARANK, CUPDAT, DEFER, MWPLAN

Table C5-3 (contd.)

Variable	Type	Dimension	Unit	Storage Location	Accessed from	Used by
FIPLOC	Real		Codelist I	//	DG 70	NEWPLT
FIRTYP	Real		Codelist B	//	DG 70	NEWPLT
FRACT	Real		Fraction			PLAN
FRCBLT	Real		Fraction			DRANK
GEN	Real		GWh	//	DG 70	NEWPLT
GENET	Real		Billion KWh	//	DG 15	TDGNA
GENETL	Real		Billion KWh	/PLNSTA/		TDGNA
HEATR8	Real		Btu/KWh	//	DG 70	NEWPLT, NEWSCH
HR8NEW	Real	23	Btu/KWh	/PLNMTL/	DG 20	NEWPLT, NEWSCH, PLAN
HR8SCH	Real		Btu/KWh	//	DG 23	NEWSCH
IBDYR	Integer		Index			ADVANC, ARANK
IBPOLD	Integer		Index			DRANK
ICONV	Integer					UPSCHD
IRANK	Integer	300		//		ADVANC, ARANK, DEFER, DRANK
ISTATE	Integer		Codelist I		Argument	ADVANC, ARANK, DEFER, DRANK, NEWPLT, NEWSCH, PLAN, POLPEN, TDGNA, UPSCHD
ITECH	Integer			Codelist B	Argument	ADVANC, NEWPLT
ITRACE	Integer				Argument	ADVANC, ARANK, DEFER, PLAN, POLPEN, TDGNA, UPSCHD
IYEAR	Integer		Year		Argument	ADVANC, ARANK, DEFER, PLAN, POLPEN, TDGNA, UPSCHD
IYEAR1	Integer		Year		Argument	ADVANC, ARANK, DEFER,

Table C5-3 (contd.)

Variable	Type	Dimension	Unit	Storage Location	Accessed from	Used by
						PLAN, POLPEN, TDGNA, UPSCHD
KDEF	Integer					DRANK
KHRZ	Integer				Argument	ADVANC, ARANK, DEFER, DRANK, NEWSCH, PLAN
KOST	Integer	300		//		ARANK, DRANK, POLPEN, UPSCHD
LSTSTA	Real		Codelist I	//		PLAN, TDGNA
MIXOFF	Integer					ADVANC
NADVBL	Integer				Argument	ADVANC, ARANK
NDEF	Integer					UPSCHD
NDEFRD	Integer					ARANK, DEFER
NDFRBL	Integer				Argument	DEFER, DRANK
NEWNUC	Integer					ADVANC, ARANK, UPSCHD
NHORIZ	Integer					PLAN
NOXDV	Integer		Codelist F	//	DG 23	NEWSCH
NPLT	Integer				LENGTH(70, ISTATE)	PLAN
NRETRO	Integer				LENGTH(32, ISTATE) LENGTH(33, ISTATE) LENGTH(34, ISTATE)	POLPEN
NSCH	Integer				LENGTH(23, ISTATE)	ARANK, DRANK
NSCHLD	Integer					ADVANC
NUCPRC	Integer					NUCSTG
NUCTEK	Integer		Codelist B			ADVANC, ARANK, NUCSTG, UPSCHD
OANDM	Real		Mills/KWh	//	DG 70	NEWPLT

Table C5-3 (contd.)

Variable	Type	Dimension	Unit	Storage Location	Accessed from	Used by
OMNEW	Real		Mills/KWh	/PLNATL/	DG 20	NEWPLT, PLAN
PCT	Real		percent	//	DG 23	NEWSCH, UPSCHD
PEAKD	Real		MW	//	DG 15	PLAN, TDGNA
PEAKMX	Real		MW	/PLNATL/		TDGNA
PKADD	Real		MW			UPSCHD
PKFRAC	Real		Fraction			PLAN
PRIME	Real		Codelist A	//	DG 70	NEWPLT, NEWSCH, UPSCHD
PRIMSC	Real		Codelist A	//	DG 23	NEWSCH
PRJPLD	Real	15	MW	//	DG 14	PLAN
PRJQEL	Real	15	Billion KWh	//	DG 14	PLAN
PTYPE	Real	23	Codelist A	/PLNATL/	DG 20	NEWPLT, PLAN
RETIRE	Real		Year	//	DG 70	NEWPLT, PLAN, POLPEN, UPSCHD
SEQNO	Real			//	DG 70	ADVANC, NEWSCH, PLAN, POLPEN, UPSCHD
SIZEMW	Real		MW		Argument	ADVANC, CUPDAT, DEFER
SIZNEW	Real	23	MW	/PLNATL/	DG 20	ADVANC, ARANK, DRANK, NEWPLT, PLAN
SOXDV	Real		Codelist E	//	DG 23	NEWSCH
SPKFRC	Real	2	Fraction	/PLNSTA/	DG 21	PLAN
SPREAD	Real			//	DG 20	ARANK, DRANK, NEWSCH, NUCSTG, PLAN
STAGE	Real			//	DG 23	ARANK, DRANK,

Table C5-3 (contd.)

Variable	Type	Dimension	Unit	Storage Location	Accessed from	Used by
						NEWSCH, NYDEFD, UPSCHD
SYSIZE	Real	45	MW	//	DG 24	CUPDAT, DEFER, POLPEN, UPSCHD
TCCNOX	Real		Million $	//	DG 23	NEWSCH
TCCPLT	Real		Million $	//	DG 23	NEWSCH
TCCSOX	Real		Million $	//	DG 23	NEWSCH
TCCTSP	Real		Million $	//	DG 23	NEWSCH
TECH	Real		Codelist B	//	DG 70	NEWPLT, NEWSCH, PLAN, POLPEN, UPSCHD
TECHSC	Real		Codelist B	//	DG 23	ADVANC, ARANK, CUPDAT, DEFER, DRANK, NEWSCH, NYDEFD, UPSCHD
TOTITC	Real			//	DG 23	NEWSCH
TOTPEN	Real		MW		Argument	PLAN, POLPEN, UPSCHD
TOTSCH	Real		MW	//		ADVANC, UPSCHD
TSPDV	Real		Codelist D	//	DG 23	NEWSCH
TVCPC	Real		$/Year	//	DG 70	NEWSCH
UNITNO	Real		Hollerith string	//	DG 70	NEWPLT
UNITR	Real				DG 32,33,34	POLPEN
UNITSC	Real			//	DG 23	ADVANC, ARANK, DEFER, DRANK, NEWSCH, PLAN, UPSCHD
USER	Real			PLAN		

Table C5-3 (contd.)

Variable	Type	Dimension	Unit	Storage Location	Accessed from	Used by
VCAP	Real	135			DG 24	PLAN
VDEM	Real	34				PLAN
VDEM	Real	8				TDGNA
VEST	Real		Million $	//	DG 23	UPSCHD
VNATL	Real	483			DG 20	PLAN
VRETRO	Real	3			DG 32,33,34	POLPEN
VSCHED	Real	23			DG 23	ADVANC, ARANK, DEFER, DRANK, UPSCHD
VSTATE	Real	8			DG 21	POLPEN
VTDGNA	Real	3			DG 22	TDGNA
VUNIT	Real	22			DG 70	ADVANC, PLAN, POLPEN, UPSCHD
XMULT	Real			//	DG 70	NEWPLT, PLAN
XPDLIF	Real	23		/PLNATL/	DG 20	ADVANC, DEFER, PLAN, UPSCHD
YEARON	Real		Year	//	DG 70	NEWPLT, NEWSCH, PLAN, UPSCHD
YRBGUN	Real		Year	//	DG 23	ADVANC, DEFER, NEWSCH, NYDEFD, UPSCHD
YROFF	Real		Year			PLAN
YRONSC	Real		Year	//	DG 23	ADVANC, ARANK, DEFER, DRANK, NUCSTG, POLPEN, UPSCHD

[a] // denotes location of variable in blank common.

C6. THE POLLUTION CONTROL MODULE

by

J.F. Skea, W. Gooding and C.N. Bloyd

Universities Research Group on Energy
Carnegie-Mellon University

6.1 Overview

The pollution control module of the Advanced Utility Simulation Model (AUSM) is exercised in two parts, each called independently of the other from the control program. The COMPLY module has the following main tasks:

1. Choosing the coal and pollution control strategy that will result in the lowest cost of electric power for new coal-fired plants beginning construction. (Or at all coal-fired plants under construction in the first year of the simulation.
2. Supervising the on-going construction of pollution control equipment at existing plants.
3. Updating the fuel and pollution control information for existing plants as they attain compliance with emission standards.
4. Assigning pollution control annual variable costs and capacity penalties at operating coal-fired plants in the first year of the simulation.
5. Determining the appropriate choice of coal and pollution control strategies at existing coal-fired plants that are required to comply with a specified set of emission standards.
6. Determining the level and type of SO_2 pollution abatement of each generating unit under a market management approach when the user requests such an approach. Determination is based on the marginal costs of each abatement strategy. (This optional feature of the model is described in Chapter C6a.)

Figure C6-1 shows a schematic of the COMPLY module. It is divided into three main sections. In the first section, the construction schedule for new units (Data Group 23) is scanned and task 1 is performed. In the second section, the retrofit construction schedules (Data Groups 32, 33 and 34) are scanned and tasks 2 and 3 are performed. In the third section, the unit inventory (Data Group 70) is scanned and tasks 4 and 5 are performed. Figure C6-2 shows a schematic of module data inputs and outputs.

The main function of the IMPACT module is to calculate the emission of pollutants from fossil fuel power plants and the variable cost of pollution control at coal-fired plants in each year of the simulation. Because emissions and costs depend on the dispatching of individual plants, the module is called from the control program immediately after the call to the dispatch module. The tasks of the IMPACT module are straightforward. Figure C6-3 shows a schematic of the control logic and Figure C6-4 shows the input and output.

6.2 Operation

6.2.1 COMPLY

6.2.1.1 Scenario Variables, New Source Performance Standards and Fuel Costs. In the first year of the simulation, values for the pollution control scenario variables are obtained from Data Group 30, and values for the required global scenario variables are read in. These values are stored in the common block CTNATL for the duration of the simulation. Planning data for new unit construction is obtained from Data Group 20. Each year, financial data is obtained from Data Groups 60 and 61, the New Source Performance Standards (NSPS) are obtained from Data Group 31, and the technology switches are set. Finally, the default properties of fuels other than coal are obtained from Data Group 74, the tax depreciation schedule appropriate for new units is obtained from Data Group 60, and the present worth of depreciating $1 is calculated.

6.2.1.2 Scan of the Construction Schedule for New Units. Data Group 23 is scanned each year to determine any plants in the schedule that must have fuel data assigned to the corresponding entry in the unit inventory (Data Group 70). If the plants are coal-fired, a coal and pollution control strategy must be

Figure C6-1

COMPLY FLOWCHART

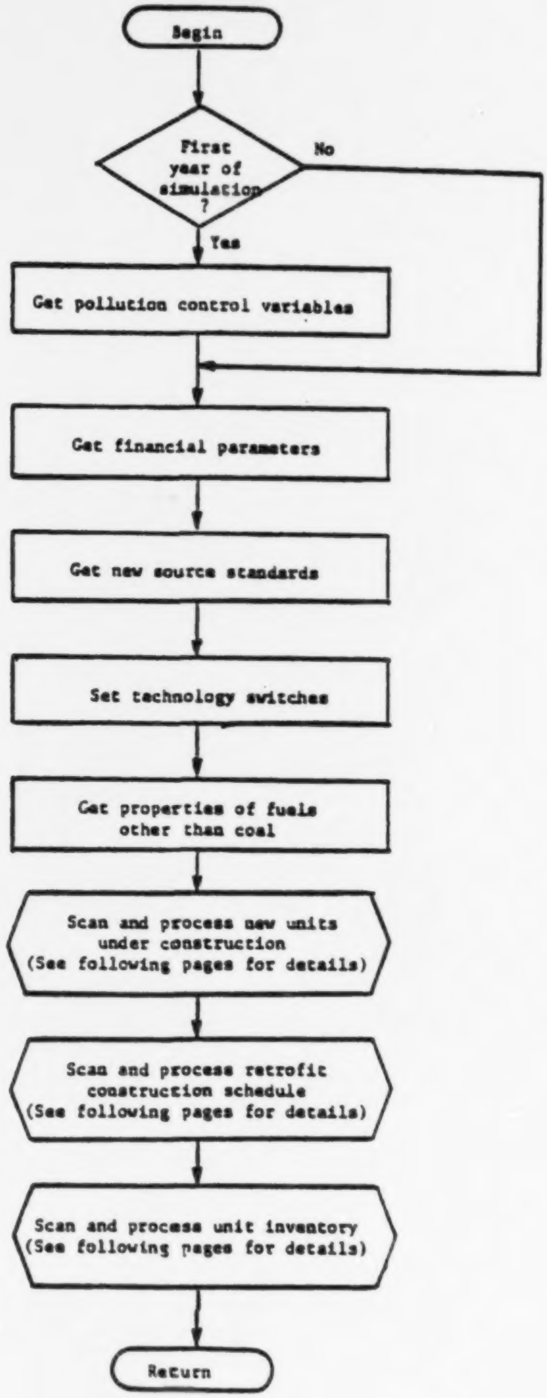

Begin
First year of simulation ?
No
Yes
Get pollution control variables
Get financial parameters
Get new source standards
Set technology switches
Get properties of fuels other than coal
Scan and process new units under construction (See following pages for details)
Scan and process retrofit construction schedule (See following pages for details)
Scan and process unit inventory (See following pages for details)
Return

Figure C6–1 (contd.)

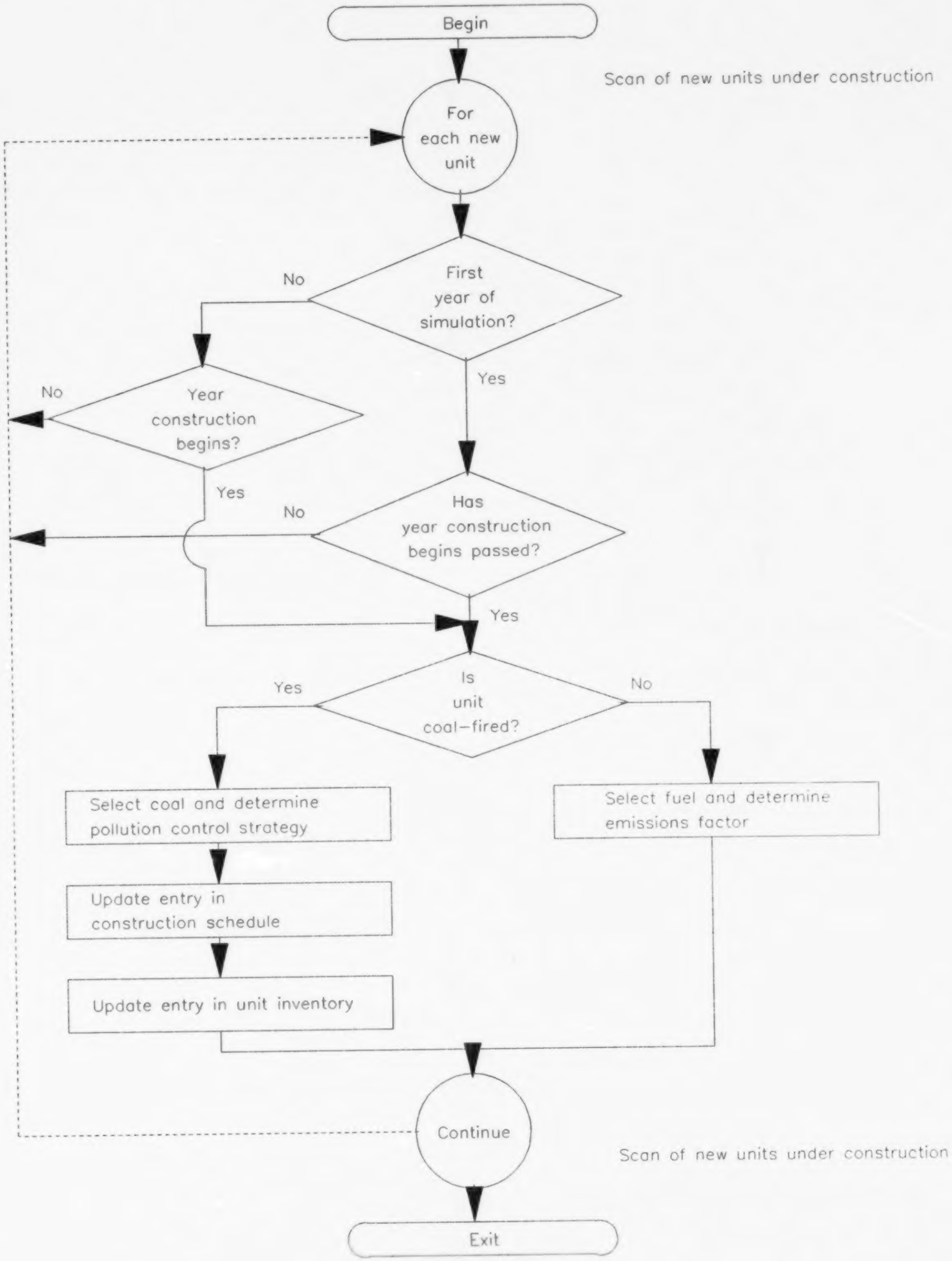

Begin
Scan of new units under construction
For each new unit
First year of simulation?
No
Yes
Year construction begins?
No
Yes
Has year construction begins passed?
No
Yes
Is unit coal–fired?
Yes
No
Select coal and determine pollution control strategy
Update entry in construction schedule
Update entry in unit inventory
Select fuel and determine emissions factor
Continue
Scan of new units under construction
Exit

Figure C6–1 (contd.)

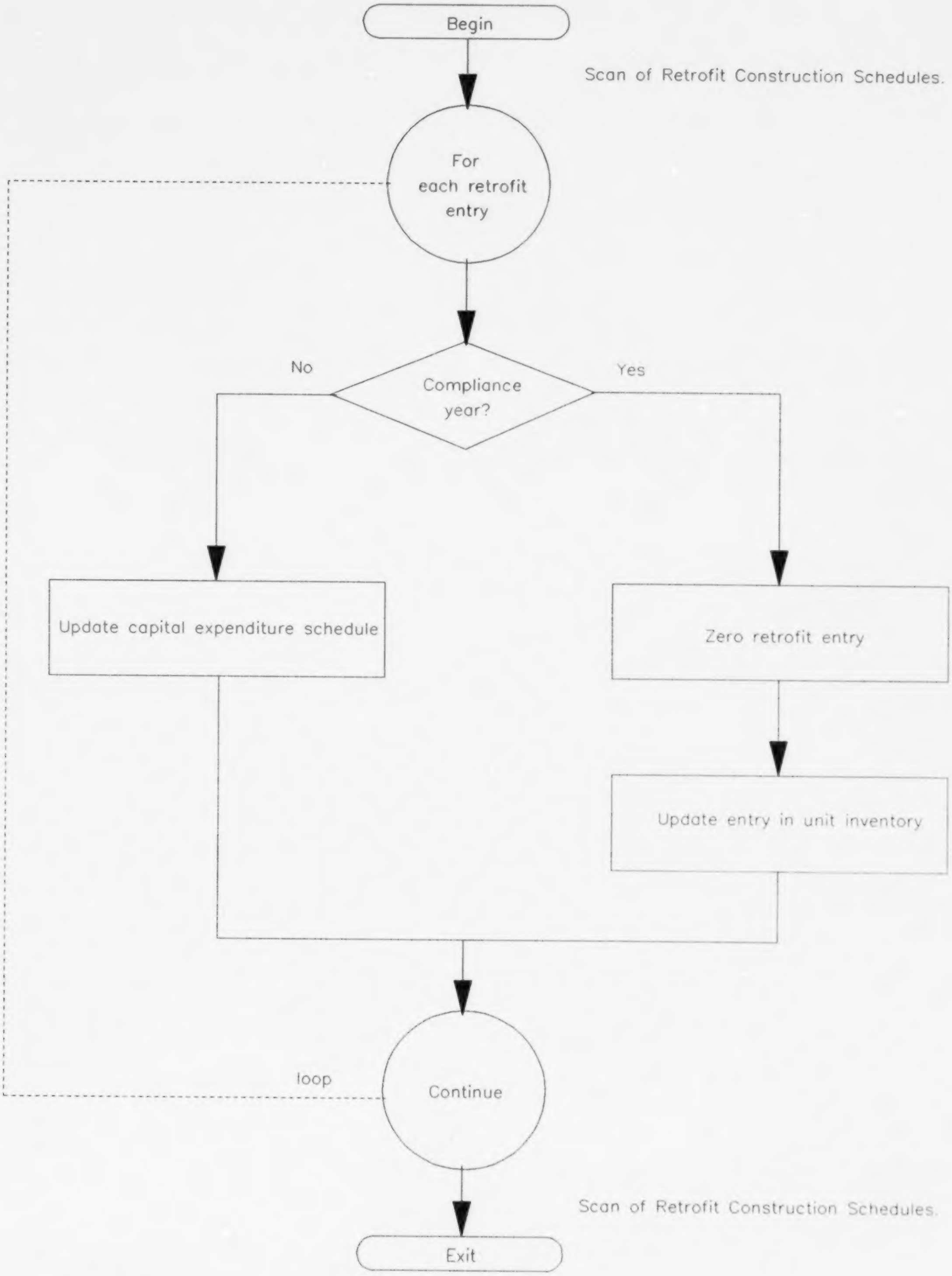

Begin
Scan of Retrofit Construction Schedules.
For each retrofit entry
No
Compliance year?
Yes
Update capital expenditure schedule
Zero retrofit entry
Update entry in unit inventory
loop
Continue
Scan of Retrofit Construction Schedules.
Exit

Figure C6-1 (contd.)

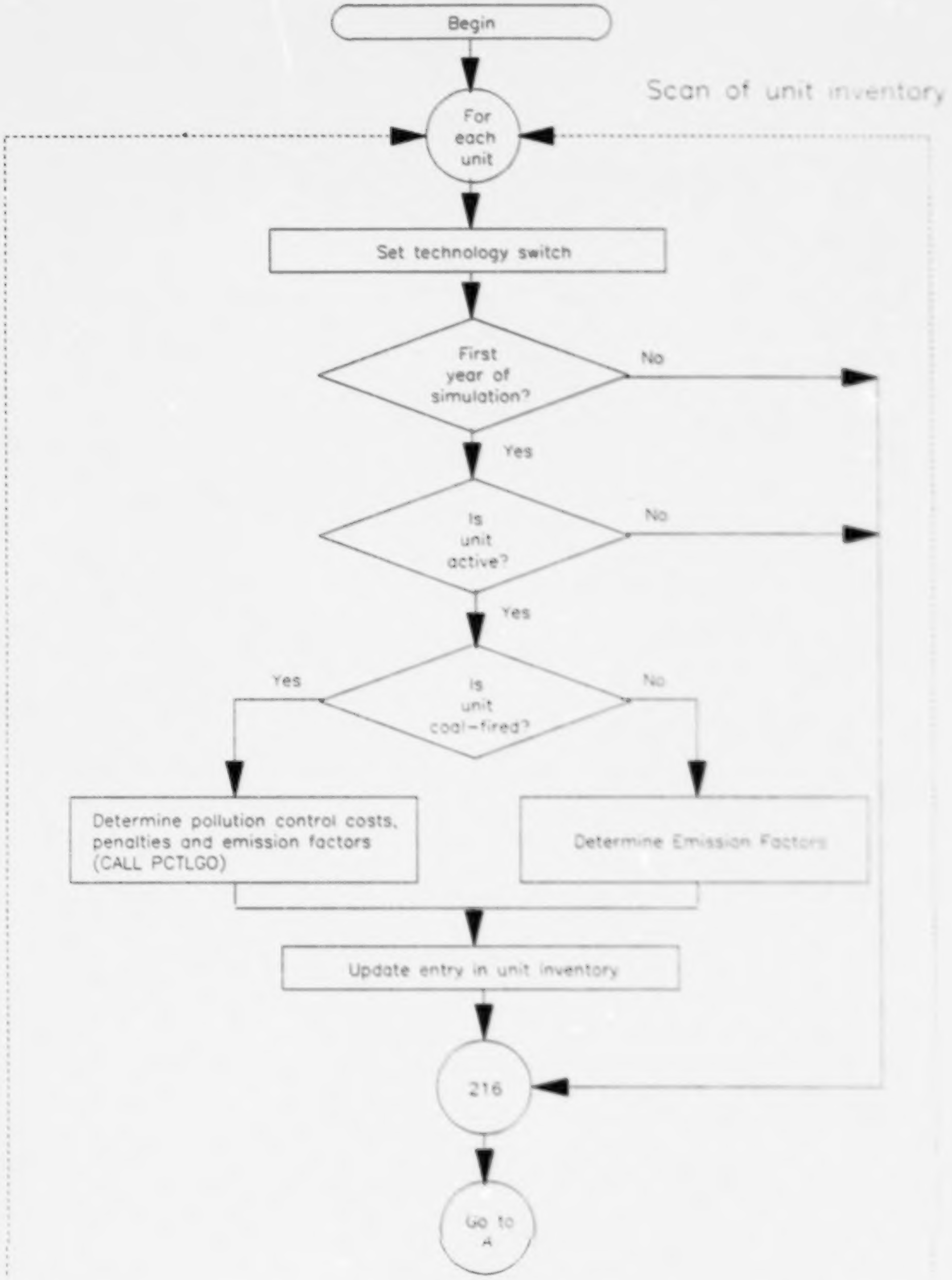

Begin
Scan of unit inventory
For each unit
Set technology switch
First year of simulation?
No
Yes
Is unit active?
No
Yes
Is unit coal-fired?
Yes
No
Determine pollution control costs, penalties and emission factors (CALL PCTLGO)
Determine Emission Factors
Update entry in unit inventory
216
Go to A

Figure C6–1 (contd.)

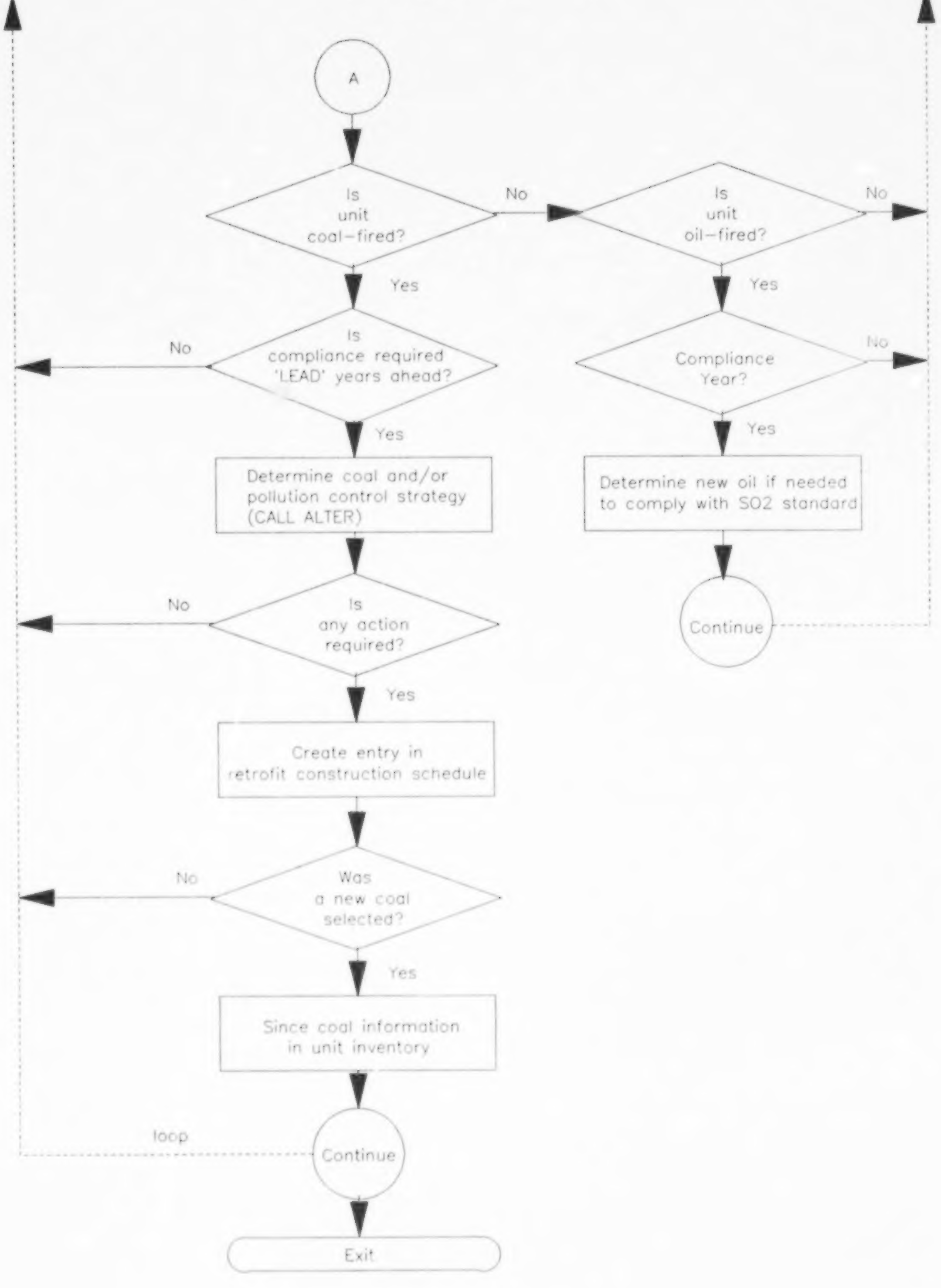
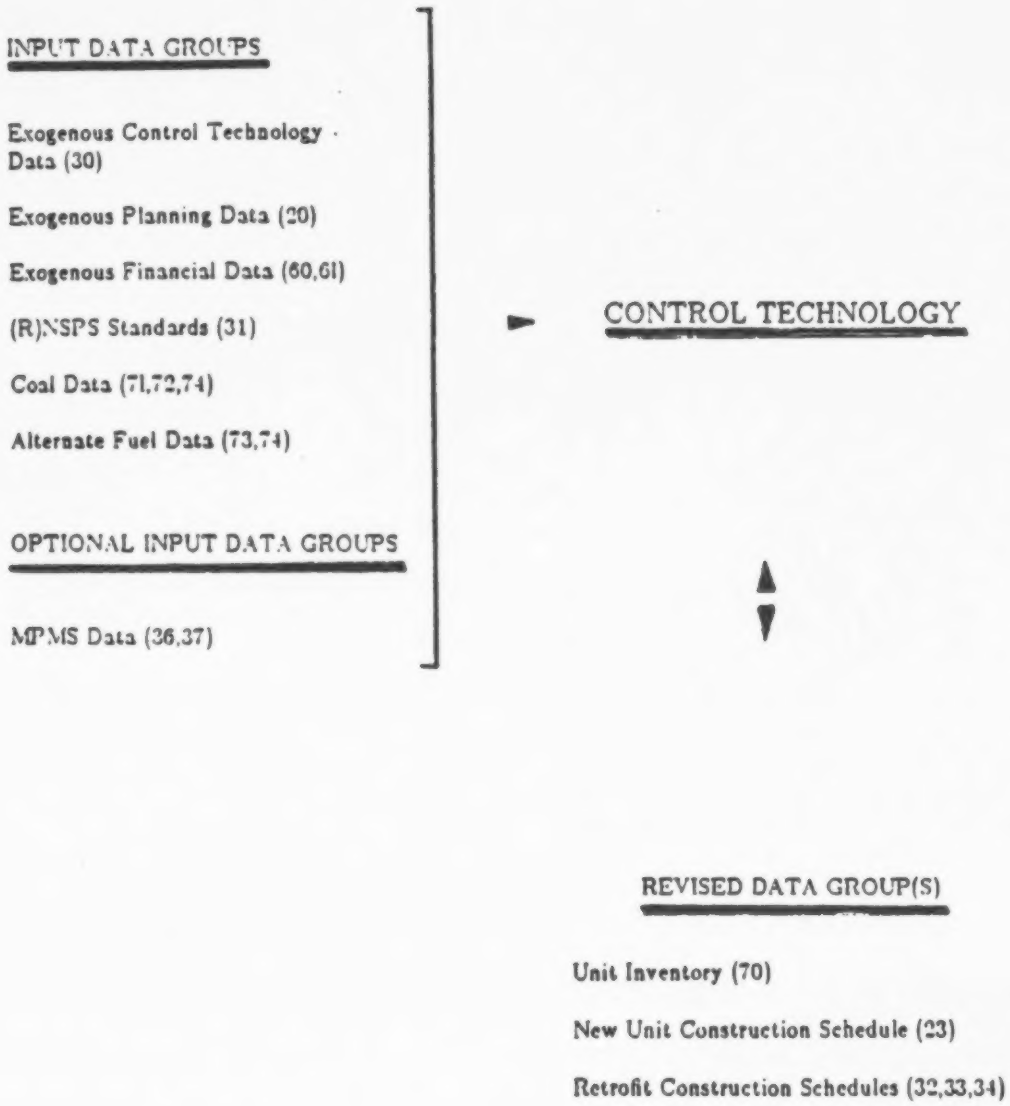

A
Is unit coal-fired?
No
Is unit oil-fired?
No
Yes
Yes
No
Is compliance required 'LEAD' years ahead?
Compliance Year?
No
Yes
Yes
Determine coal and/or pollution control strategy (CALL ALTER)
Determine new oil if needed to comply with SO2 standard
Continue
No
Is any action required?
Yes
Create entry in retrofit construction schedule
No
Was a new coal selected?
Yes
Since coal information in unit inventory
loop
Continue
Exit

Figure C6-2

CONTROL TECHNOLOGY DATA FLOW



INPUT DATA GROUPS

Exogenous Control Technology Data (30)

Exogenous Planning Data (20)

Exogenous Financial Data (60,61)

(R)NSPS Standards (31)

Coal Data (71,72,74)

Alternate Fuel Data (73,74)

OPTIONAL INPUT DATA GROUPS

MPMS Data (36,37)

CONTROL TECHNOLOGY

REVISED DATA GROUP(S)

Unit Inventory (70)

New Unit Construction Schedule (23)

Retrofit Construction Schedules (32,33,34)

Figure C6-3
IMPACT FLOWCHART

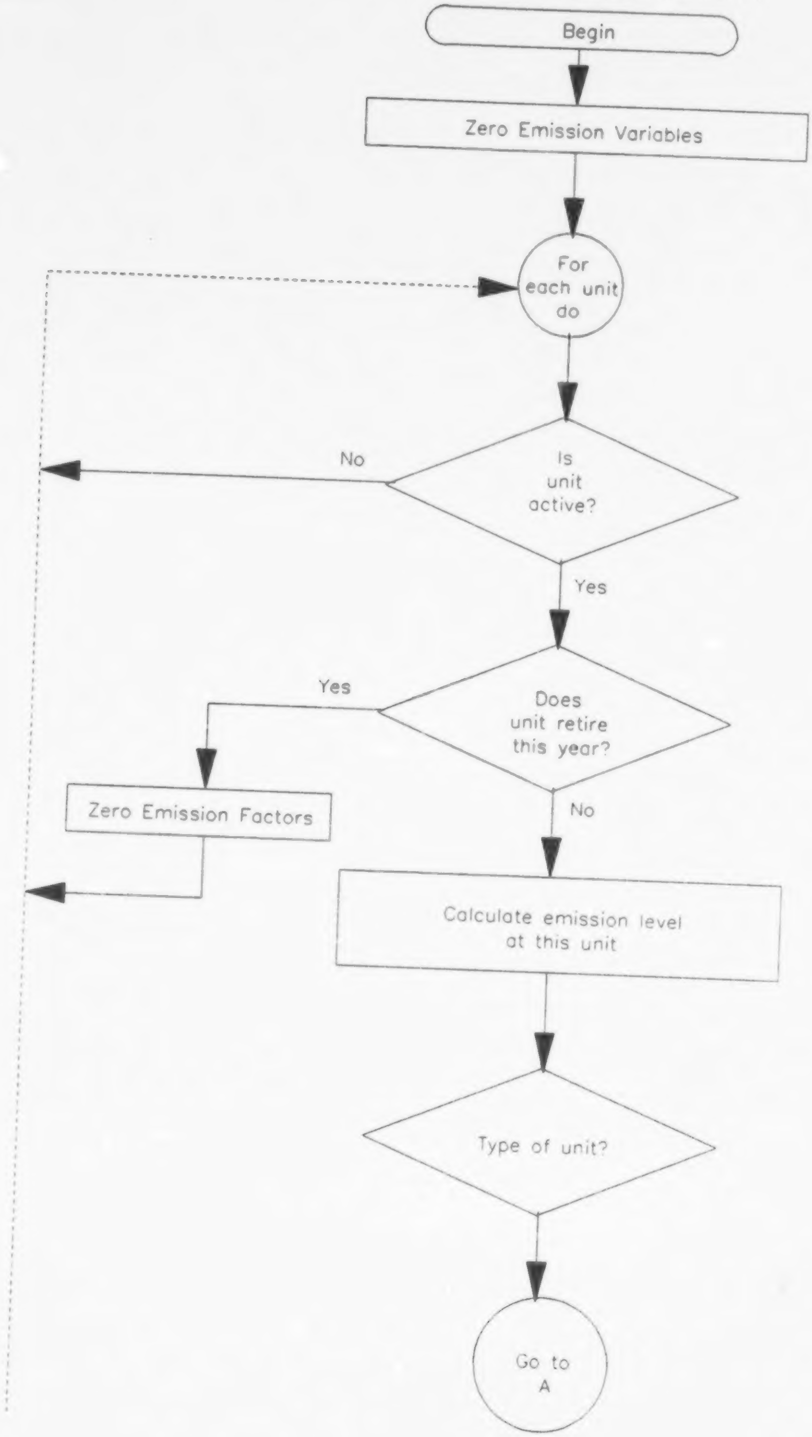


Figure C6-3 (contd.)

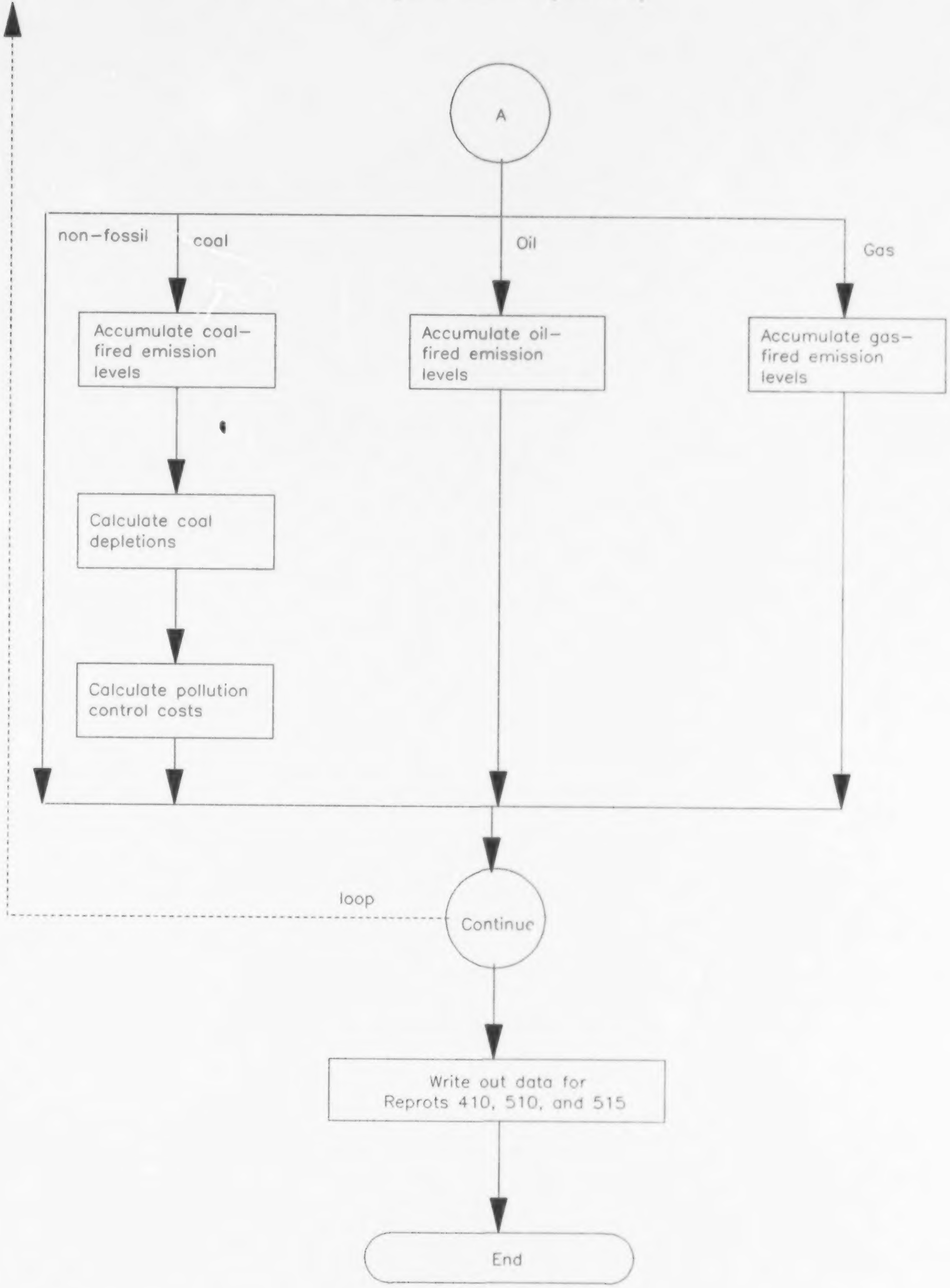

A
non-fossil
coal
Oil
Gas
Accumulate coal-fired emission levels
Calculate coal depletions
Calculate pollution control costs
Accumulate oil-fired emission levels
Accumulate gas-fired emission levels
loop
Continue
Write out data for Reprots 410, 510, and 515
End

Figure C6-4
IMPACT DATA FLOW

INPUT DATA GROUPS

Exogenous Control Technology Data(30)

Unit Inventory(70)

➤ IMPACTS

chosen. Information on the choice is written to the corresponding entry in the unit inventory, and the capital costs are added to the construction schedule for new units.

Each unit in the schedule is examined in turn. In the first year of the simulation, all units in the schedule are examined, while in subsequent years any unit commencing construction is examined and all others are ignored. For noncoal-fired units, the default fuel properties, fuel cost and emission factors are assigned to the unit inventory.

If a coal plant is encountered, the subroutine ALTCOL is called to obtain a list of the properties and costs of all the cheapest alternative coals of each type and in each sulfur category delivered to this demand region in the year that the plant commences operation. This list is created by the coal preprocessor (see Section 8). A total of 33 coals for AUSM cost model data base and 40 for EIA data base are obtained. ALTCOL calculates an adjusted sulfur content for each coal to allow for the retention of sulfur in ash and a 'relative standard deviation' sulfur content to allow for the interaction of sulfur variability in the coal and the averaging time for emissions specified in the NSPS. Additionally, ALTCOL calls LVLCST to estimate the levelized cost of each coal over the plant lifetime. LVLCST gives appropriate weights to each member of a set of future costs to derive the levelized cost.

ALTER is called to determine the appropriate coal and pollution strategy for each plant. For new plants, ALTER sets up the plant lifetime and lifetime capacity factor, and examines each alternative coal offered to the plant in turn, setting the required sulfur removal according to the sulfur content of the coal under consideration. The coal with the lowest overall cost (fuel plus pollution control) levelized over the plant lifetime is selected. CNTROL is called to determine the least cost pollution control strategy for each coal. CNTROL looks at each possible method of SO_2 control in turn and selects the one that will give the least overall levelized pollution control cost. This cost comprises the costs of SO_2, TSP and NO_x control plus those of waste disposal. The particular method of SO_2 control chosen can affect all the other cost items. The levelized costs include capital (fixed) costs, annual variable costs and the cost associated with the capacity penalty caused by the addition of pollution control equipment.

Reproduced from
best available copy.

In COMPLY, the characteristics of the coal chosen and the pollution control information are added to the plant entry in Data Group 70. The capital costs associated with the different items of pollution control equipment are added to the entry in the construction schedule for new units, Data Group 23.

6.2.1.3 **Scan of the Retrofit File**. Each entry in the retrofit schedules (Data Groups 32, 33, and 34) is examined in turn. Currently, new entries in the three retrofit schedules are created simultaneously, i.e., if an entry is made in one schedule, an entry is always made in the other two. This is more fully discussed in Section 6.2.1.4. Since the three schedules are the same length, it is easy to pick up corresponding entries in each schedule.

The entries are tested to see if the pollution control equipment is due to come on-line in the current year. If not, the 'current stage of construction' in each schedule is deduced from the construction time required for the pollution control device, the current year and the on-line year. The fraction of the capital costs expended in the current year is updated by referring to the construction cost schedule for the device.

If the on-line year has been reached, the following steps are taken: The capital cost fractions in the retrofit file are zeroed since construction is at an end. The SO_2 compliance strategy is then read from the retrofit file. All fuel data is read in from the unit inventory file. If a new coal has been chosen, its characteristics are moved from the compliance coal section to the average coal section of the unit inventory file. If the new coal is not a blend, then its properties are written directly into the average fuel portion. If the new coal is a blend with the original first coal, the compliance coal will contain only the second coal data and the Btu fraction of the second coal (which will be less than 1.0). The properties of the blend are then calculated and moved into the compliance coal section.

The regulatory information regarding the plant is then obtained from the unit inventory. If it is a compliance year for a particular pollutant, the emission standard is updated by moving the new standard into the current standard slot. The pollution control data in the unit inventory is then updated using the information that has been stored in the retrofit schedules.

6.2.1.4 **Scan of the Unit Inventory**. Each entry in the inventory is scanned each year. In the first year of the simulation, plants fired on fossil fuels other than coal have their emission factors set. For coal-fired plants, PCTLGO is called to determine a capacity penalty for the pollution control equipment already installed, the unit variable costs of pollution control, the bypass fraction on any scrubber and the emission factors. The capacity penalty is added to the 'current capacity' at the plant to estimate the true 'initial capacity.'

For each plant the number of years remaining before compliance with SO_2, TSP, or NO_x emission standards is checked. If the remaining number of years coincides with the maximum pollution control construction period (lead time), COMPLY proceeds to choose the pollution control strategies. First, ALTCOL is called to obtain a set of alternative coals selected by the coal preprocessor. The procedure is the same as described in Section 6.2.1.2 except that only 11 (AUSM) or 8 (EIA) coals are obtained. This is because at an existing plant it is assumed that the same type of coal (i.e., bituminous, sub-bituminous or lignite) must always be used. ALTER then steps through each candidate coal, including the plant's existing coal, to determine whether the plant will be in compliance with new standards and, if it will not, to determine an appropriate compliance strategy.

For existing plants, if no action is required to attain SO_2 compliance, ALTER considers only the existing coal at the plant. If action is required, BLEND is called either to re-blend the cement blend if possible or to create new coals that are mixtures of the current first coal used at the plant and the different alternative coals. ALTER then examines the current coal, each of the alternative coals plus any blends created. ALTER loops over each candidate coal and selects the coal that has the lowest annual levelized cost over the lifetime of the plant, including pollution control costs. The pollution control costs are calculated in CNTROL as for new plants. CNTROL excludes combinations of SO_2 control method, coal and SO_2 removal level which are considered incompatible or which are restricted by the specified scenario. For example, a control technology may not be available in the compliance year or the user may require scrubbing at all plants. The plants are tested for TSP and NO_x compliance in CNTROL, and removal efficiencies are adjusted if necessary and appropriate costs calculated in TSPBLD and NOXBLD. Note that even if there is no compliance year for these pollutants, capital costs may be incurred because emission levels are not allowed to increase when a switch to a new coal is made. The SO_2 control method that results in the lowest overall pollution control cost is selected.

If any action was required to achieve compliance, new entries are created in each of the retrofit schedules, Data Groups 32-34. This 'lockstep' treatment of the retrofit schedules proves convenient, because the capacity penalty and variable costs of pollution control cover SO_2, TSP, NO_x control and waste disposal. All data passed from ALTER is added to the appropriate retrofit schedules. The properties of the new coal are placed in the 'compliance coal' slots in the unit inventory, Data Group 70. If the new coal is not a blend, its 'fraction used' is set to 1.0. If it is a blend, the Btu fraction of the coal in the blend is assigned. The 'net' capacity is assigned to Data Group 32 (that means the new capacity penalty minus the old one). Other values assigned to the retrofit schedules are the current stages of construction for each of the control devices, and the fractions of the total capital costs of each of the devices incurred in the current year.

6.2.2 IMPACT

Each year, every plant in the unit inventory is scanned. However, only fossil fuel plants (coal, residual oil, distillate oil and gas) are considered. IMPACT identifies the fuel used and goes to the corresponding section of code. For oil- and gas-fired plants, the emission factors and the electricity dispatched from the plant (as previously determined by the dispatch module) are used to calculate the emission of each pollutant (SO_2, TSP and NO_x) from each plant. These emissions are accumulated for each fuel type.

For coal-fired plants, the previously outlined steps are taken, but in addition, the plant characteristics and capacity factor are used to calculate the variable cost of pollution control. The quantities of ash and FGD sludge created are also calculated and are accumulated to obtain a state total.

6.3 Data Handling

6.3.1 COMPLY

6.3.1.1 Scenario Variables and Fuel Properties

Data Group	Access	Circumstances	Data Elements	Variable Names
Scenario	GETSCN	Every year	52	YRONE
30	GET	First year of simulation	All	CTNATL
Scenario	GETSCN	First year of simulation	501-504, 510-513 54, 62, 68, 66, 71-74	CTNATL
20	SGET	First year of simulation	376-387, 107, 130	CTNATL
60	SGET	Each year	62, 68, 90, 91	CTNATL
61	SGET	Each year	2, 3, 8, 9	CTNATL
31	GET	Each year	All	CTNATL
74	GET	Each year	All	ALTFUL
60	SGET	Each year	47-61	TXSCHD

6.3.1.2 Scan of the Construction Schedule for New Units

Data Group	Access	Circumstances	Data Elements	Variable Name
23	SGET	Once for every entry	1,3,4,5,10,22	IUNSEQ,YRBGUN, YEARON,ITCHCD, GEN,HEATRT
23	SPUT	For every coal fired unit which has a coal and pollution control strategy selected	11-17, 21	SO2DV,TCCFGD, TSPDV,TCCTSP, NOXDV,TCCNOX CAPPEN,TVCPC
70	SPUT	As above	24-27,30-47	COLDAT
70	SPUT	As above	13,23,49,53,57, 60-64,67-72	GEN,SO2STD, TSPSTD,NOXSTD, SO2DV,SO2REM, BYPASS,SO2MWH, NOXREM,TSPDV, TSPREM,TSPMWH, NOXDV,NOXREM, TVCPC
73	GET	For every noncoal-fired unit whose fuel properties must be assigned	All	VLIST

Data Group	Access	Circumstances	Data Elements	Variable Names
70	SGET	As above	19	BOLTYP
70	SPUT	As above	23-27, 63, 68, 71	VLIST

6.3.1.3 Scan of the Retrofit File

Data Group	Access	Circumstances	Data Elements	Variable Names
32	GET	For every entry	All	IUNSEQ,SO2DV, ICMPLY,CAPPEN, TVCPC,SO2REM
33	GET	For every entry	All	NOXDV,NOXREM
34	GET	For every entry	All	TSPDV,TSPEM
32	PUT	Once for every entry that has not yet reached the compliance year	All	IDXSO2,FGDEXP
33	PUT	As above	All	IDXNOX,NOXEXP
34	PUT	As above	All	IDXTSP,TSPEXP
32	PUT	Once for every plant that has reached the compliance year	All	FGDEXP
33	PUT	As above	All	NOXEXP
34	PUT	As above	All	TSPEXP
70	SGET	Every complying entry with a new coal	60	SO2DV
70	SGET	Every plant attaining compliance	24-27, 30-47	COLDAT
70	SPUT	Every plant with a new coal	24-27, 30-47	COLDAT
70	SGET	Every plant attaining compliance	11-13,18,19,22 49-51,53-55, 57-60	INOXCP,NOXSDI, ISO2CP,SO2SDI, ITSPCP,TSPSDI, TSPSDN,GRSGEN, GEN,HEATRT, RETIRE,BOTTYP, BOLTYP,SO2DVO SO2SDN, NOXSDN
70	SPUT	As above	13,49,53,57,	SO2SDI,TSPSDI,

Data Group	Access	Circumstances	Data Elements	Variable Names
			60-64,67-72	NOXSDI,SO2DV, BYPASS,SO2MWH, NOXDV,NOXREM, NOXMWH,TSPDV, TSPREM,TSPMWH, GEN,TVCPC

6.3.1.4 Scan of the Unit Inventory File

Data Group	Access	Circumstances	Data Elements	Variable Names
35	GET	Once for every entry in the EPOS control file	All	UNEPOS,TCHEPS
70	SGET	Every entry in the Unit File	11-13,18-23, 48,50,51,54,55 58-62,64,67,69 70,72	HEATRT,GRSGEN, OMCOST,RETIRE, IFCODE,REGCAT, SO2STD,ISO2CP, TSPSTD,ITSPCP, NOXSTD,INOXCP, SO2DV,SO2REM, BYPASS,TSPDV,TSPREM NOXDV,NOXREM, TVCPC,YEARON, GEN,BOTTYP, BOLTYP
70	SGET	Every active coal-fired plant in the first year	24-26	HHV,ASH,SULFUR
70	SPUT	Every active plant in the first year	12,62,63,68, 71,72	GRSGEN,TVCPC, BYPASS, SO2MWH, TSPMWH,NOXMWH
70	SGET	Every coal-fired plant which has a compliance year "LEAD" years ahead	24-27,30-47	COLDAT
32	SPUT	Every coal-fired plant which must do something to achieve compliance	1-7,11,12	IUNSEQ,SO2DV, TCCFGD,ICMPLY, IDXSO2,FGDEXP, CAPPEN,TVCPC, SO2REM
34	SPUT	As above	1-7,11,12	IUNSEQ,TSPDV, TCCTSP,ICMPLY, IDXTSP,TSPEXP, TSPREM
33	SPUT	As above	1-7,11,12	IUNSEQ,NOXDV, TCCNOX,ICMPLY, IDXNOX,NOXEXP, NOXREM

Data Group	Access	Circumstances	Data Elements	Variable Names
70	SPUT	Every coal-fired plant which will use a new coal	42-47	COLDAT
70	SGET	Every oil-fired plant	24,25,27,63	OILHHV,OILSUL, OILPRC,SO2MWH
70	SGET	Every oil-fired plant required to switch oil to meet SO_2 compliance	24,25,27,60,63	OILHHV,OILSUL, OILPRC,SO2MWH

6.3.1.5 In Subroutine ALTCOL

Data Group	Access	Circumstances	Data Elements	Variable Names
75	GET	Every time routine is called	All	YEARS
71	GET	Once for every existing plant	All	PRICE
71	GET	As above	All	PRICE
72	GET	Once for every alternative coal	All	COALS

6.3.1.6 In Subroutine LVLCST

Data Group	Access	Circumstances	Data Elements	Variable Names
71	GET	Every time routine is called	All	PRICE

6.3.2 IMPACT

Data Group	Access	Circumstances	Data Elements	Variable Names
70	GET	Once for every unit	All	V

6.3.3 Reports Written

Routine	Report Number	Circumstances	Variables Names
COMPLY	305	Once every year	SCBOLD,SCBNEW
IMPACT	805	Every active unit	UNSEQ,TCHCDE,HEATRT,NETGEN, CAPFAC,ENERGY,YEARON,RETIRE, FTYPE,FUELYR,PRICE,SO2TYP, TSPTYP,NOXTPY,SO2DV,TSPDV, NOXDV,OMCOST,TVCPC,SO2REM, BYPASS,SO2MWH
IMPACT	505	Every year	SO2CYR,SO2OYR,SO2GYR,NOXCYR, NOXOYR,NOXGYR,TSPCYR,TSPOYR,

Data Group	Access	Circumstances	Data Elements	Variable Names
			TSPGRY,TASHYR,TFGDSG	
IMPACT	510	As above	ICOLCT,DEPLTN	
IMPACT	515	As above	ICOLCT,DEPLTN	

Table C6-1
SYNOPSES OF MAJOR SUBPROGRAMS

Name	Synopsis	Called by
ALTCOL	Reads in the alternative coal characteristics from Data Group 72	COMPLY
ALTER	Chooses the coal and the pollution control equipment which will result in the least-cost emission control strategy at a particular plant	COMPLY
BLEND	Blends alternative coals with the current coal at an existing plant if the resulting blend would meet the SO_2 standard and if it offers a large enough cost saving over the unblended alternative	ALTER
CNTROL	Selects the cheapest combination of pollution control equipment which will result in compliance when a particular coal is being considered at a plant	ALTER
COMPLY	Driver program for pollution control	Control Program
DISPSL	Calculates the capital, variable and levelized costs of solid waste disposal (FGD sludge + ash) at either new or existing plants	CNTROL,PCTLGO
EMITRT	Calculates the emission factors (lbs/MWh) for plants fired on fossil fuels other than coal	COMPLY
FGDCST	Determines the capital cost, annual variable cost, and capacity penalty associated with a specified type of SO_2 control system	CNTROL,IMPACT, PCTLGO
IMPACT	Calculates the pollution control variable costs and emission rates at individual plants, then aggregates by fuel type over the entire state being simulated. It is called by the MAIN PROGRAM after the DISPATCH module in the annually recursive loop, so that actual plant capacity factors are used	Control Program
NOXBLD	Determines the appropriate type of NO_x control at a plant given the desired removal. Calculates the capital cost, annual cost, capacity penalty and levelized cost	CNTROL,IMPACT
OILSWH	Compares the emissions from an existing oil plant with the SO_2 standard and determines the heating	COMPLY

Table C6-1 (contd.)

Name	Synopsis	Called by
	value, sulfur content, and price of a new oil if one is needed to meet compliance	
PCTLGO	Estimates unknown pollution control parameters in the first year of the simulation	COMPLY
TSPBLD	Determines the cheapest TSP control device for a particular plant and calculates the costs and capacity penalty associated with it	CNTROL
TSPCST	Calculates the costs and capacity penalty associated with a particular TSP control device used at a particular plant. Allows for the possibility of upgrading existing equipment and will adjust the required TSP removal efficiency upward if the existing device is capable of 'over-complying'	TSPBLD, PCTLGO IMPACT

6.4 Subroutine Descriptions

Table C6-1 summarizes the major subroutines and Table C6-2 offers synopses of utility subroutines. Figures C6-5 and C6-6 show the calling sequence of the major subroutines.

Figure C6-5
CALLING SEQUENCE FOR MAJOR SUBPROGRAMS--COMPLY

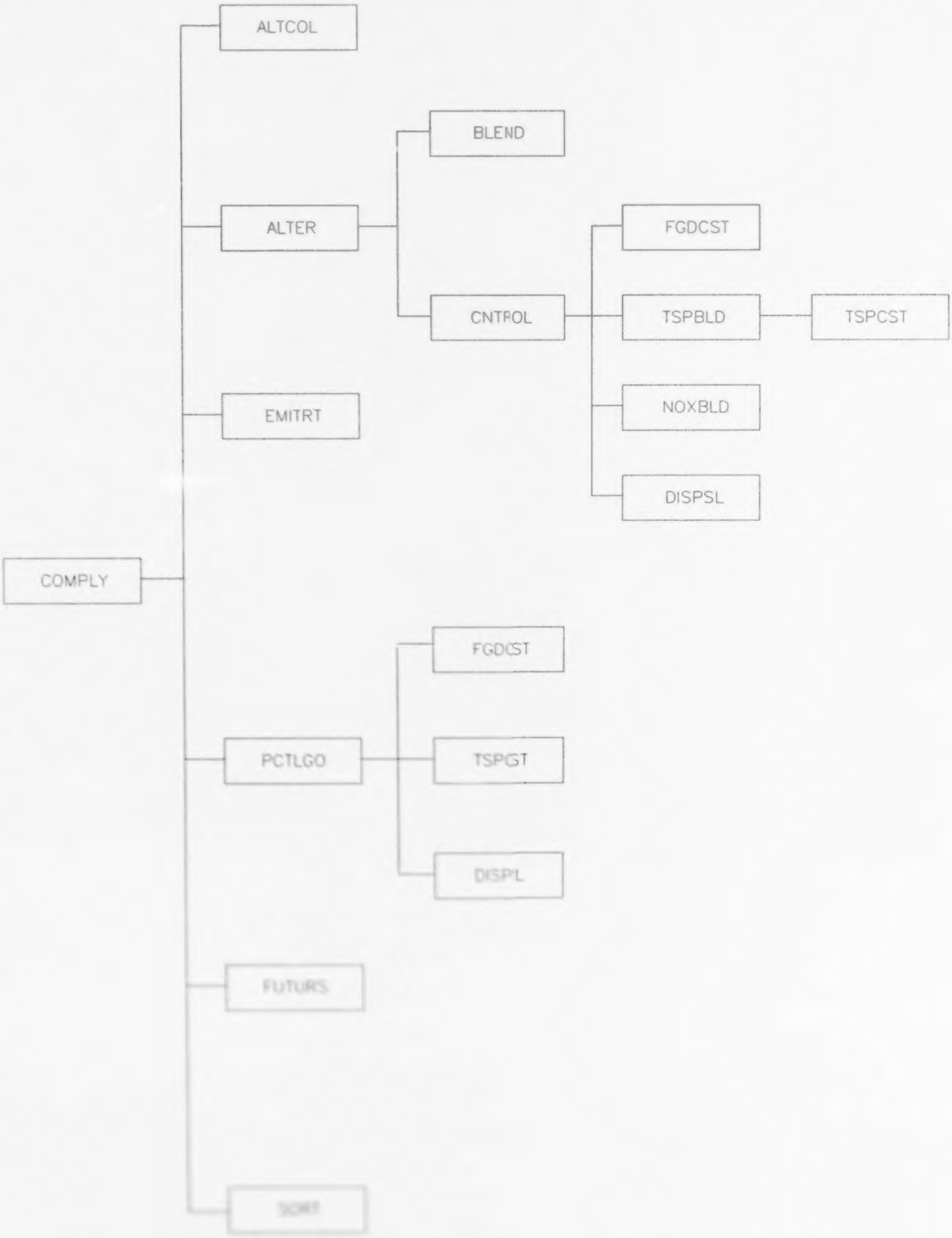


Figure C6-6

CALLING SEQUENCE FOR MAJOR SUBPROGRAMS -- IMPACT

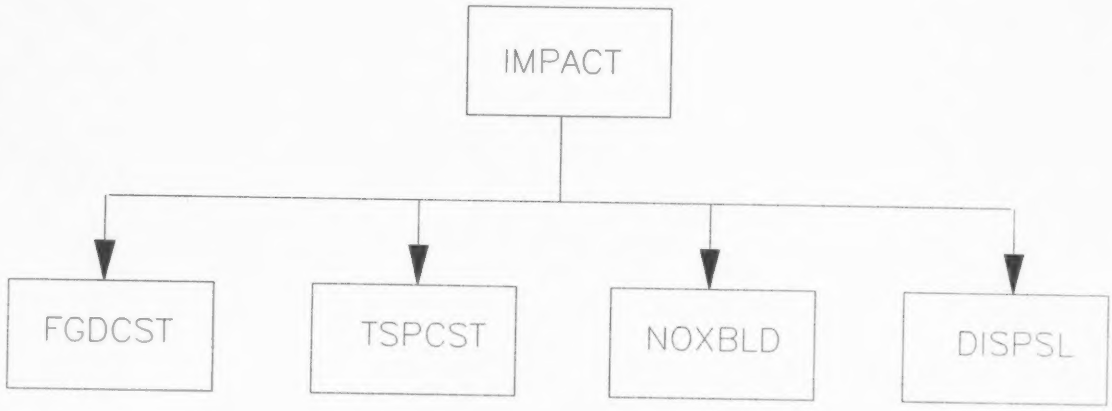


Table C6-2
SYNPOSES OF UTILITY SUBROUTINES

Name	Synopsis
CALBYP	Calculates scrubber bypass and efficiency
CAPCFC	Calculates a real levelized capital cost factor
CCESPC	Calculates the cold ESP capital cost
CCESPH	Calculates the hot ESP capital cost
CCFAB	Calculates the fabric filter capital cost
CCFGDD	Calculates the capital cost of a dry FGD
CCFGDU	Calculates the capital cost of upgrading an FGD
CCFGDW	Calculates the capital cost of a wet FGD
CCLIMB	Calculates the capital cost of LIMB
CCNOX	Calculates the capital cost of any NO_x control device
CCWAST	Calculates the capital cost of waste disposal facilities
CNSCHD	Calculates the accumulated capital costs, construction work in progress and investment tax credit during a construction schedule
COLRAT	Calculates the coal mass flow rate in tons per day at 100 percent capacity factor
CPCTY	Determines the appropriate capacity factor assumed in COMPLY from the remaining useful life of the plant
ESCLTE	Calculates the escalation rate linking two prices at two points in time
ESPCPC	Calculates the cold ESP capacity penalty in MW
ESPCPH	Calculates the hot ESP capacity penalty in MW
FABACR	Calculates the required air-to-cloth ratio of a fabric filter
FGACFM	Calculates the gas flow rate in ACFM
FGDCPD	Calculates the dry FGD capacity penalty in MW
FGDCPW	Calculates the wet FGD capacity penalty in MW

Table C6-2 (contd.)

Name	Synopsis
FLYIDX	Identifies the correct index for the flyash fraction at a coal-fired plant
FMASH	Calculates the ash removal rate in tons per hour
FMSUL	Calculates the SO_2 removal rate in tons per hour
FRAC	Calculates the fraction of two coals in a blend required to meet an SO_2 standard
FREMA	Calculates the coal-ash-removal rate necessary to meet a TSP standard
FREMN	Calculates the NO_x removal rate necessary to meet a standard
FREMS	Calculates the sulfur removal rate necessary to meet an SO_2 standard
FSCA	Calculates cold ESP specific collection area in sq ft per ACFM
FSCAH	Calculates hot ESP specific collection area in sq ft per ACFM
LMBCAP	Calculates the LIMB capacity penalty in MW
LVLCST	Calculates the levelized cost of burning a coal over a plant lifetime, given estimated costs at various points in the future
LVLFAC	Calculates a levelization factor given a nominal interest rate, an inflation rate and an escalation rate.
NOXCAP	Calculates the NO_x control capacity penalty in MW.
NOXIDX	Identifies the correct index for the NO_x emission factor at a coal-fired plant
PV	Calculates a present value factor from a discount rate
PWDEPR	Calculates the present worth of a depreciation schedule
RREC	Calculates the levelized cost of pollution control equipment from the capital cost, variable cost, and capacity penalty
SLUDGE	Calculates scrubber sludge removal in tons per hour at peak load

Table C6-2 (contd.)

Name	Synopsis
SULASH	Calculates the coal sulfur content adjusted for sulfur retention in the ash
SULVAR	Calculates coal sulfur relative standard deviation (RSD) based on coal type, averaging time, and exemption status
VCESP	Calculates precipitator variable costs
VCFAB	Calculates fabric filter variable costs
VCFGDD	Calculates dry FGD variable costs
VCFGDW	Calculates wet FGD variable costs
VCLIMB	Calculates LIMB variable costs
VCNOX	Calculates NO_x control variable costs
VCWST	Calculates waste disposal variable costs
WSR	Calculates the weight stoichiometric ratio for a dry or wet scrubber system

6.4.1 Detailed Descriptions of Major Subroutines

6.4.1.1 Subroutine ALTCOL

Task: Reads alternative coals for a specified plant from the coal file and assigns them to the COALS array.

Called by: COMPLY

Calls: ESCLTE, LVLCST, GET, SULASH, SULVAR, MMFCAT

Arguments: IYEAR, ISTATE, YEARON, RETIRE, RTRFIT

Method: Straightforward apart from prices and sulfur contents. For new plants, a set of prices covering a number of years in the future is used to calculate a levelized cost over the lifetime of the plant in LVLCST. The sulfur contents are adjusted for 1) sulfur retention in ash and 2) sulfur variability. The routine also estimates the levelized cost of using the current coal, determines the higher heating category of the current coal, and calculates levelized costs only for new coals of the same type assuming that its price evolves in the same way as the alternative coal of the same type and sulfur category.

6.4.1.2 Subroutine ALTER

Task: Determines whether a plant is in SO_2, TSP and/or NO_x compliance and, if it is not, selects an appropriate pollution control strategy.

Called by: COMPLY

Calls: BLEND, CNTROL, COLRAT, CPCTY, FGACFM, FREMS

Arguments:

Input
GRSGEN, HEATRT, BOTTYP, BOLTYP, SO2DV, SO2STD, SO2REM, BYPASS, TSPDV, TSPSTD, TSPREM, NOXDV, NOXSTD, NOXREM, RTRFIT, RETIRE, IYEAR, ISO2CP, ITSPCP, INOXCP, TCHSW, DRYSW, LIMBSW

Output
SO2DV, SO2REM, TSPDV, TSPREM, NOXDV, NOXREM, NEWCOL, TCCFGD, TCCTSP, TCCNOX, CAPPEN, TVCPC

Method: For a new plant (RTRFIT = 0), looks at each alternative coal while for an existing plant (RTRFIT = 1) looks at each alternative coal plus the existing coal and any blends which are created by BLEND. For new plants, the SO_2 control standards are set as a task of the coal properties. For each coal examined, CNTROL is called to establish the cost of the required pollution control equipment. The coal with the lowest overall levelized cost over the plant lifetime (including pollution control costs) is selected. The variable TCHSW is used to control forced scrubbing or forced switching options at existing plants by restricting the coals which can be examined.

6.4.1.3 Subroutine BLEND

Task:	Blends all the alternative coals with the first coal in the current blend if 1) the alternative coal would meet the standard by itself and 2) the cost of the resulting blend has at least a 2 percent advantage over the unblended alternative.
Called by:	ALTER
Calls:	FRAC
Arguments:	SO2STD (All the coal data is transfered in the COLINF common block.)
Method:	Considers each alternative coal in turn, derives the blend properties if it is permitted and increments the size of the alternative coal array by one.

6.4.1.4 Subroutine CNTROL

Task:	Given the properties of a particular coal which is being examined, control equipment for SO_2, TSP and NO_x is selected which will result in compliance with standards and will give the lowest annual levelized cost over the plant lifetime.
Called by:	ALTER
Calls:	DISPSL, FGDCST, FLYIDX, FMASH, FMSUL, FREMA, FREMN, NOXBLD, RREC, TSPBLD, TCHSW
Arguments:	*Input* GRSGEN, HEATRT, G, BOTTYP, BOLTYP, CAPFAC, RTRFIT, PRJTIM, SO2STD, TSPSTD, NOXSTD, ISO2CP, ITSPCP, INOXCP, IYEAR, DRYSW, LIMBSW, COAL, COLTYP, COALM, COALMO, SO2DV, SO2REM, SO2RMO, BYPASS, TSPDV, TSPREM, TSPRMO, NOXDV, NOXREM, NOXRMO *Output* SO2DV, SO2REM, BYPASS, TSPDV, TSPREM, NOXDV, NOXREM, TCCFGD, TCCTSP, TCCNOX, TVCPC, CAPPEN, LVLCOS
Method:	Examines each possible type of SO_2 control in turn (including no device). Infeasible combinations of devices, coals and SO_2 removals are excluded, as are dry FGD and/or LIMB if the relevant switches are not set. Calls FGDCST to determine the cost of each SO_2 control device. Since the choice of SO_2 device can effect TSP and/or NO_x control costs, control of these pollutants is determined within the main do-loop TSPBLD is called to determine the cheapest method of TSP control, and NOXBLD performs the same task for NO_x control. The details of cheapest overall pollution control strategy are passed back to ALTER.

6.4.1.5 Subroutine COMPLY

Task: COMPLY determines pollution control strategy for new plants in Data Group 23; updates the retrofit files (Data Groups 32 - 34), bringing pollution control equipment on line and introducing new coals where appropriate; and determines the pollution control strategy for exsting plants when compliance is required. Initial pollution control costs and capacity penalty are established during the first year of the simulation.

Called by: Control Program

Calls: ALTCOL, ALTER, CALBYP, CPCTY, EMITRT, FLYIDX, GET, GETSCN, LENGTH, NOXIDX, PCTLGO, PUT, PWDEPR, SGET, SPUT, SULASH, SULVAR, OILSWH, MMFCAT

Arguments: IYEAR, ISTATE, ITRACE

Method: During the new unit scan, assigns the default fuel properties at plants other than coal-fired ones. For coal-fired plants, ALTER is called to identify the coal and pollution control strategy that will result in the lowest busbar cost of electricity. During the retrofit file scan, the retrofit files are updated in years prior to pollution devices coming on line, and adjustments are made to the unit inventory file when plants do come into compliance with emission standards. During the unit inventory scan, in the first year of the simulation the initial values of pollution control variables at coal-fired plants are calculated by calling PCTLGO. In other years, coal-fired plants are tested to see if they are close to a compliance year. If they are, ALTCOL is called to obtain a list of alternative coals and ALTER is called to identify the cheapest pollution control strategy. An entry is created in the retrofit files for all noncompying plants.

6.4.1.6 Subroutine DISPSL

Task: Calculates the capital, variable and annual levelized costs of waste disposal.

Called by: PCTLGO, CNTROL, IMPACT

Calls: CCWAST, RREC, SLUDGE, VWAST, WSR

Arguments: *Input*
BYPASS, CAPFAC, GEN, MAREMN, MAREMO, MSREMN, MSREMO, PRTIM, RTRFIT, SO2DV, SO2VO, SO2REM

Output
TCCWST, TVCWST, WSTLV

Method: If an SO_x control device is inplace, calculates the sludge removal rate. Then calls the basic pollution controlcost tasks.

6.4.1.7 Subroutine EMITRT

Task:	Determines SO_2, TSP and NO_x emission factors (lbs/MWh) for plants fired on fossil fuels other than coal.
Called by:	COMPLY
Arguments:	*Input* IFCODE, YEARON, HEATRT, HHV, SULFUR, BOLTYP *Output* SO2MWH, TSPMWH, NOXMWH
Method:	Determines whether the plant is SIP, NSPS, or RNSPS according to its on-line date. Uses EPA emission factors for SIP plants and for other plants sets the emission rates according to the EPA emission factors or the appropriate set of standards, whichever gives the lowest value.

6.4.1.8 Subroutine FGDCST

Task:	Calculates the capital cost, annual cost and capacity penalty for a specified SO_2 control system given the required removal efficiency.
Called by:	CNTROL, PCTLGO, IMPACT
Calls:	CALBYP, CCFGDD, CCFGDU, CCFGDW, FGDCPD, FGDCPW, FMSUL, VCFGDD, VCFGDW, WSR, CCLIMB, LMBCAP, VCLIMB
Arguments:	*Input* CAPFAC, COALM, COLADJ, COLRSD, G, GRSGEN, HEATRT, RTRFIT, SO2DV, SO2RMN, SO2RMO *Output* CAPFGD, TCCFGD, TVCFGD, SO2RMN, BYPASS
Method:	Goes to the correct section of code according to the type of device requested and calls the basic pollution control subroutines. Allows for upgrading if necessary.

6.4.1.9 Subroutine IMPACT

Task:	Calculates the emissions, pollution control costs and solid waste creation at each fossil fuel power plant. Accumulates the emissions of each type of pollutant over the entire state.
Called by:	Control Program
Calls:	COLRAT, DISPSL, FGACFM, FGDCST, FLYIDX, FMASH, FMSUL, GET, LENGTH, NOXBLD, SLUDGE, SPUT, SULASH, TSPCST, WSR, MMFCAT
Arguments:	IYEAR, ISTATE, ITRACE
Method:	Scans each plant in the unit inventory file and determines which fuel is used. Calculates the emissions of SO_2, TSP and NO_x from the emission factors and electricity generation. For coal-fired plants, also calculates the variable cost of pollution control and the creation of ash and scrubber sludge for disposal.

6.4.1.10 **Subroutine NOXBLD**

Task: Determines the appropriate method of NO_x control according to boiler characteristics and requested removal efficiency. Calculates the capital cost, annual cost, capacity penalty and annual levelized cost.

Called by: CNTROL, IMPACT

Calls: CCNOX, NOXCAP, RREC, VCNOX

Arguments: *Input*
BOLTYP, CAPFAC, GEN, NOXDVO, NOXRMN, NOXRMO, PRJTIM, RTRFIT, SO2DV

Output
LVLNOX, NOXRMN, TCCNOX, TVCNOX, NOXDVN, PENLTY

Method: Determines the correct method according to whether the plant is new or existing, the boiler and firing types and the requested NO_x removal. Sets NO_x removal on a fixed basis and calculates the capital costs, annual costs, capacity penalty and annual levelized costs.

6.4.1.11 **Subroutine OILSWH**

Task: Compares the existing emissions to the SO_2 standard. If existing emissions exceed the SO_2 standard, computes the fractional reduction of sulfur needed to meet compliance. Then computes heating value, sulfur content, and price of the new oil.

Called by: COMPLY

Calls: EMITRT

Arguments: *Input*
HEATRT, ITRACE, OILHHV, OILPRC, OILSUL, SO2MWH, SO2STD

Output
NEWOIL, OILHHV, OILPRC, OILSUL, SO2MWH

Method: If the current oil is in compliance, return to COMPLY. Otherwise, computes the heating value, sulfur content, and price of the compliance oil. Set the logical variable NEWOIL=TRUE to signify a new oil was selected.

6.4.1.12 **Subroutine PCTLGO**

Task: Estimates the unit cost of pollution control, the capacity penalty associated with pollution control and the scrubber bypass (if any) at existing coal-fired plants in the first year of the simulation. Sets the emission factors for SO_2, TSP and NO_x.

Called by: COMPLY

Calls: COLRAT, CPCTY, DISPSL, FGACFM, FGDCST, FLYIDX, FMASH, FMSUL, NOXIDX, SULASH, TSPCST

Arguments: *Input*

BOTTYP, BOLTYP, COLASH, COLHHV, COLSUL, COLTYP, GEN, HEATRT, NOXDV, NOXREM, RETIRE, SO2DV, SO2REM, TSPDV, TSPREM, YEARON

Output
BYPASS, CAPPEN, NOXMWH, SO2MWH, TVCPC, TSPMWH

Method: Calls the basic pollution control cost tasks.

6.4.1.13 Subroutine TSPBLD

Task: Determines the cheapest type of TSP control and its cost.

Called by: CNTROL

Calls: RREC, TSPCST

Arguments:

Input
ASHN, ASHO, CAPFAC, COALMN, COALMO, G, GEN, IDXFLY, PRJTIM, RTRFIT, SO2DV, SULFN, SULFO, TSPDVO, TSPRMN, TSPRMO

Output
CCTSP, LVLTSP, PENLTY, TSPRMN, TSPDVN, VCTSP

Method: Calls TSPCST for each possible type of TSP device in turn, then estimates the total levelized cost associated with it. Finally identifies the cheapest method. The methods are, with their codes:

1) Mechanical
2) Cold ESP
3) Hot ESP
4) Mechanical/ESP
5) Fabric filter

6.4.1.14 Subroutine TSPCST

Task: Calculates the capital cost, variable cost and capacity penalty associated with any type of TSP device. If a similar device is already in place, the costs of upgrading are calculated.

Called by: PCTLGO, TSPBLD, IMPACT

Calls: CCESPC, CCESPH, CCFAB, ESPCPC, ESPCPH, FABACR, FSCA, FSCAH, VCESP, VCFAB

Arguments:

Input
ASHN, ASHO, CAPFAC, COALMN, COALMO, G, GEN, IDXFLY, RTRFIT, SO2DV, SULFN, SULFO, TSPDVN, TSPDVO, TSPRMN, TSPRMO, UNCOST

Output
CAPCOS, CAPPEN, TSPRMN, VARCOS, UPGRAD

Method: Goes to the correct piece of code depending on the new device required. If a device is being upgraded, the capital cost of incremental construction is calculated. If an existing device is capable of a greater efficiency than that required, the required efficiency is increased before being returned to the calling routine. The possible devices and their codes are:

1) Mechanical collection
2) Cold ESP
3) Hot ESP
4) Mechanical/ESP
5) Fabric filter

6.4.2 Detailed Description of Utility Subroutines

6.4.2.1 Subroutine CALBYP

Task: Calculates scrubber bypass and efficiency.

Arguments: *Input*
GEN, DEFSO2, FGDMIN, SO2REM

Output
BYPASS, SO2OUT

Method: Attempts to set a scrubber efficiency equal to the default (DEFSO2) by adjusting the bypass fraction. However, will not allow a scrubber size of less than FGDMIN.

6.4.2.2 Subroutine CAPCFC

Task: Calculates a real levelized capital cost factor.

Calls: PV

Arguments: *Input*
ACCCST, ADVLRM, CWIP, DISCNT, INFLAT, ITC, PRJTIM, PVDEPN, PVDEPR, RTRFIT, TAXRAT

Output
CAPCFC

Method: Uses the standard formula for a fixed charge factor explained in the analytical documentation.

6.4.2.3 Subroutine CCESPC

Task: Calculates the capital cost of a cold-side precipitator.

Arguments: *Input*
CCFACT, CNDXCP, G, GEN, ICF, RTRFCT, SCA

Output
CCESPC

Method: Exponential scaling model adjusted for cost escalation and a retrofit factor if the plant is an existing one.

6.4.2.4 **Subroutine CCESPH**

Task: Calculates the capital cost of a hot-side precipitator.

Arguments:

Input
CCFACT, CNDXCP, G, GEN, ICF, RTRFCT, SCA

Output
CCESPH

Method: See CCESPC.

6.4.2.5 **Subroutine CCFAB**

Task: Calculates the capital cost of a fabric-filter device.

Arguments:

Input
BAGCST, CCFACT, CNDXCP, FABAC, G, GEN, ICF, RTRFCT

Output
CCFAB

Method: See CCESPC.

6.4.2.6 **Subroutine CCFGDD**

Task: Calculates the capital cost of a dry scrubber.

Arguments:

Input
BYPASS, CNDXCP, CAPRSD, G, GEN, ICCOST, ICF, MSREM, RTRFCT, SO2REM, UNTCST

Output
CCFGDD

Method: See CCFGDW

6.4.2.7 **Subroutine CCFGDU**

Task: Calculates the capital cost of upgrading a scrubber to improve its efficiency.

Arguments:

Input
BYPASS, CNDXCP, GEN, ICCOST, ICF,

Output
CCFGDU

Method: Uses a dollar per kilowatt model.

6.4.2.8 **Subprogram CCFGDW**

Task: Calculates the capital cost of a wet scrubber (with or without fixed oxidation).

Arguments: *Input*
BYPASS, CNDXCP, CAPRSD, G, GEN, ICCOST, ICF, MSREM, RTRFCT, SO2REM, WFGDSW

Output
CCFGDW

Method: Decides the number of operating and redundant scrubber trains. Calculates the cost of an individual train, then the cost of the whole system. Adds in materials handling costs and multiplies by a retrofit factor for an existing plant.

6.4.2.9 **Subprogram CCLIMB**

Task: Calculates the capital cost of LIMB.

Arguments: *Input*
CAPRSD, CNDXCP, GEN, ICCOST, ICF, RTRFCT, UNTCST

Output
CCLIMB

Method: Aggregates the boiler modification and materials handling costs allowing for indirect costs and cost escalation. Boiler modification cost is assumed to include indirect costs and be directly applicable to retrofit applications.

6.4.2.10 **Subroutine CCNOX**

Task: Calculates the capital cost of NO_x control.

Arguments: *Input*
BOLTYP, CCFACT, CNDXCP, GEN, ICF, NOXDV, RTRFCT, RTRFIT

Output
CCNOX

Method: Goes to the correct section of code depending on the type of device requested. Returns to scale or $/KW models are used.

6.4.2.11 **Subroutine CCWAST**

Task: Calculates the capital cost of waste disposal facilities.

Arguments: *Input*
CNDXCP, DLNCST, GEN, ICCOST, ICFPND, ICFLF, MAREM, MSREM, RTRFCT, SOLFRC, SOLWST, SO2DV, WFGDSW

Output
CCWAST

Method: Uses returns to scale models for both ash and scrubber sludge disposal to calculate the capital costs of land and facilities using one of five methods which depend on the type of SO_2 device and, for wet FGD, a user-specified switch.

6.4.2.12 **Subroutine CNSCHD**

Task: Calculates the accumulated capital costs, construction work in progress and investment tax credit associated with one dollar of total capital costs.

Arguments:

Input
DEVCON, DISCNT, ESCAL, EXPSCH, INFLAT, ITCRAT, ITCTYP, LEAD, RTRFIT

Output
ACCCST, CWIP, ITC

Method: Runs through each year of the construction schedule, accumulating the variables taking account of inflation, real escalation and discount rates.

6.4.2.13 **Subroutine COLRAT**

Task: Calculates coal use at peak load.

Arguments:

Input
COLHHV, GEN, HEATRT

Output
COLRAT

Method: Straightforward arithmetic.

6.4.2.14 **Subroutine CPCTY**

Task: Selects an appropriate lifetime capacity factor for use in costing pollution control strategies.

Arguments:

Input
CF, IYEAR, RTRLYR

Output
CPCTY

Method: Determines the appropriate capacity factor as a task of the remaining useful life at the plant. (A step task is used.)

6.4.2.15 **Subroutine ESCLTE**

Task: Calculates the escalation rate linking two prices at two points in time.

Arguments:

Input
A, B, C, D

Output
ESCLTE

Method: Straightforward arithmetic.

6.4.2.16 **Subroutine ESPCPC**

Task: Calculates the capacity penalty of a cold-side precipitator.

Arguments: *Input*
SCA, G

Output
ESPCPC

Method: Linear task of inputs.

6.4.2.17 **Subroutine ESPCPH**

Task: Calculates the capacity penalty of a hot-side precipitator.

Arguments: *Input*
SCA, G

Output
ESPCPH

Method: See ESPCPC

6.4.2.18 **Subroutine FABACR**

Task: Computes the fabric filter air to cloth ratio.

Arguments: *Input*
ACTTEM, COALM, COLASH, FLYASH, G, OLMAX, TREMN, STDTEM

Output
FABAC, TREMN

Method: Computes the input loading and the output loading needed to achieve the desired efficiency. Adjusts the efficiency upward if the output loading is greater than the default maximum. Calculates the air to cloth ratio as a linear task of the output loading.

6.4.2.19 **Subroutine FGACFM**

Task: Calculates gas flow rate at a plant.

Arguments: *Input*
ACTTEM, ASH, COLTYP, EXAIR, GEN, HEATRT, HHV

Output
FGACFM

Method: Straightforward arithmetic.

6.4.2.20 **Subroutine FGDCPD**

Task: Calculates the capacity penalty associated with a dry scrubber.

Arguments: *Input*
BYPASS, G, HEATRT, MSREM

Output

FGDCPD

Method: See FGDCPW

6.4.2.21 Subroutine FGDCPW

Task: Calculates the capacity penalty associated with a wet scrubber.

Arguments: *Input*
BYPASS, G, HEATRT, MSREM, SULFUR, WFGDSW

Output
FGDCPW

Method: Derives the electrical penalty and the steam penalty for reheat separately and adds them together.

6.4.2.22 Subroutine FLYIDX

Task: Identifies the correct index for flyash fractions.

Arguments: *Input*
BOLTYP, BOTTYP, COLTYP

Output
FLYIDX

Method: Depends on combination of coal type, firing type and bottom type.

6.4.2.23 Subroutine FMASH

Task: Calculates ash removal rate.

Arguments: *Input*
COALM, COLASH, FLYASH, REMTSP

Output
FMASH

Method: Straightforward arithmetic.

6.4.2.24 Subroutine FMSUL

Task: Calculates SO_2 removal rate.

Arguments: *Input*
COALM, COLSUL, SO2REM

Output
FMSUL

Method: Straightforward arithmetic.

6.4.2.25 FRAC

Task: Calculates the fraction of one coal which, along with another coal, may be blended to achieve sulfur compliance.

Arguments: *Input*
SUL1, HHV1, SUL2, HHV2, SO2STD

Output
FRAC

Method: Straightforward arithmetic.

6.4.2.26 Subroutine FREMA

Task: Calculates TSP removal necessary to meet a TSP standard.

Arguments: *Input*
COLBTU, COLASH, FLYASH, TSPSTD

Output
FREMA

Method: Straightforward arithmetic.

6.4.2.27 Subroutine FREMN

Task: Calculates NO_x removal necessary to meet a standard.

Arguments: *Input*
BOLTYP, BOTTYP, COLHHV, COLTYP, EFCOAL, NOXSTD

Output
FREMN

Method: Straightforward arithmetic.

6.4.2.28 Subroutine FREMS

Task: Calculates SO_2 removal necessary to meet a standard.

Arguments: *Input*
COLBTU, DESSUL, SO2STD

Output
FREMS

Method: Straightforward arithmetic.

6.4.2.29 Subroutine FSCA

Task: Calculates specific collection area of a cold-side precipitator required to achieve a specified flyash removal.

Arguments: *Input*
COLSUL, ESPEFF, IDX

Output
FSCA

Method: Calculates the resistivity of the flyash as a task of the sulfur content of the coal. Uses this to calculate the particle drift velocity. This and the required efficiency are used to calculate the specific collection area. If IDX = 1 reverses the calculation and derives the removal efficiency from the collection area.

6.1.2.30 Subroutine FSCAH

Task: Calculates the specific collection area of a hot-side precipitator.

Arguments:

Input
ESPEFF, IDX

Output
FSCAH

Method: Uses a fixed particle drift velocity and the required efficiency to derive the result. As with FSCA, the routine can calculate the efficiency given the collection area.

6.1.2.31 Subroutine LMBCAP

Task: Calculates the capacity penalty associated with LIMB.

Arguments:

Input
CAPAVG, HEATRT

Output
LMBCAP

Method: Linear model.

6.1.2.32 Subroutine LVLCST

Task: Estimates the levelized cost of burning a coal over a specified period given the prices at various points in the future.

Calls: ESCLTE, GET, PV

Arguments:

Input
DISCNT, IDXCOL, IDXOFF, IDXON, RETIRE, YEARON, YEARS

Output
INTCST, LIFCST

Method: Derives appropriate weights for each of the known future prices and establishes a present worth for the coal costs. Converts to a levelized cost. See the analytic documentation for a description of the method.

6.1.2.33 Subroutine LVLFAC

Task: Calculates the levelization factor for a uniformly escalating stream of costs.

Calls: PV

Arguments: Input
DISCNT, ESCAL, INFLAT, LEAD, PRJTIM
Output
LVLFAC

Method: Uses the fact that a levelization factor is the quotient of two capital cost factors. Adjusts the result to take account of lead times.

6.4.2.34 Subroutine NOXCAP

Task: Calculates the capacity penalty associated with NO_x control.

Arguments: Input
GEN, NOXDV
Output
NOXCAP

Method: Proportional model for NOXDV=1 only.

6.4.2.35 Subroutine PV

Task: Identifies the correct index for NO_x emission factors for coal-fired boilers.

Arguments: Input
BOLTYP, BOTTYP, COLTYP
Output
NOXIDX

Method: Based on the combination of coal type, firing type and bottom type.

6.4.2.36 Subroutine PV

Task: Calculates a present value factor from a discount rate.

Arguments: Input
DISCNT, LIFE
Output
PV

Method: Standard present value formula.

6.4.2.37

Task: Computes higher heating value, sulfur content, emissions, and price of a compliance oil.

Arguments: ITRACE, SO2STD, HEATRT, OILHHV, OILSUL, OILPRC, SO2MWH, NEWOIL

Method: If existing emissions exceed the SO_2 standard, the functional reduction of sulfur is computed to achieve a new heating value, sulfur content, emissions value and price using the method suggested by Capone and Collins in report "Cost of Fuel Oil by Sulfur Content" (Task 5, EPA Contract 68-02-3694)

6.4.2.38 Subroutine PWDEPR

Task: Calculates the present worth of depreciating one dollar of investment over a specified schedule.

Calls: PV

Arguments:

Input
DISCNT, TYPE, TXSCHD

Input
PWDEPR

Method: For new plants, discounts each year of the schedule separately. For retrofit pollution control equipment, uses PV since there is a simple 5-year straight line schedule.

6.4.2.39 Subroutine RREC

Task: Computes annual levelized cost associated with building and operating a pollution control device.

Calls: CAPCFC, CNSCHD, LVLFAC

Arguments:

Input
CAPFAC, CAPPEN, DEVTYP, PRJTIM, RTRFIT, TCC, TVC

Output
RREC

Method: Determines a fixed charge factor by getting the accumulated capital costs, construction work in progress and investment tax credit form CNSCHD. Adds together the levelized variable costs, the annualized cost of capital and the levelized cost of the capacity penalty.

6.4.2.40 Subroutine SLUDGE

Task: Calculates rate of FGD sludge removal.

Arguments:

Input
MSREM, SOLFRC, SO2DV WFGDSW, WTSTRT

Output

SLUDGE

Method: SO_2 removal rate times the stoichiometry, divided by the solid waste fraction.

6.4.2.41 Subroutine SULASH

Task: Calculates sulfur content adjusted for ash retention.

Arguments:

Input
ASHRET, COLSUL, COLTYP

Output
SULASH

Method: Reduces the sulfur content by a fixed fraction depending on the coal type.

6.4.2.42 Subroutine SULVAR

Task: Adjusts sulfur content for variability and the averaging time specified in an emission regulation.

Arguments:

Input
AVGTMS, COLCLE, COLSUL, COLTYP, EXMLTS, RSD, YEARON

Output
SULVAR

Method: Adjusts the sulfur content by a fixed fraction dependent on
1) whether the coal is cleaned bituminous or not.
2) the exemption status of the plant.
3) the averaging time specified in the regulation.

6.4.2.43 Subroutine VCESP

Task: Calculates the variable cost of operating a precipitator.

Arguments:

Input
CF, CNDXCP, G, IVCOST, SCA

Output
VCESP

Method: Linear model.

6.4.2.44 Subroutine VCFAB

Task: Calculates the variable cost of operating a fabric filter.

Arguments:

Input
BAGCST, CF, CNDXCP, FABAC, G, GEN, IVCOST,

Output
VCFAB

Method: Linear model which includes the cost of bag replacement.

6.4.2.45 Subroutine VCFGDD

Task: Calculates the variable cost of operating a dry scrubber.

Arguments: *Input*
BYPASS, CAPAVG, CF, CNDXVP, GRSGEN, IVCOST, RC, SO2REM

Output
VCFGDD

Method: See VCFGDW

6.4.2.46 Subroutine VCFGDW

Task: Calculates the variable cost of operating a wet scrubber.

Arguments: *Input*
BYPASS, CAPAVG, CF, CNDXVP, G, IVCOST, MSREM, RC, SO2REM, WFGDSW

Output
VCFGDW

Method: Linear models for operation and materials handling.

6.4.2.47 Subroutine VCLIMB

Task: Calculates the variable cost of operating a LIMB.

Arguments: *Input*
CAPAVG, CF, CNDXVP, IVCOST, RC, UNTCST

Output
VCLIMB

Method: Linear models.

6.4.2.48 Subroutine VCNOX

Task: Calculates the variable cost of NO_x control.

Arguments: *Input*
BOLTYP, CF, CNDXCP, GEN, NOXDV, VCFACT, RTRFIT

Output
VCNOX

Method: Goes to the correct section of code depending on the device specified and the boiler type. Linear models are used.

6.4.2.49 Subroutine VCWAST

Task: Calculates the annual variable cost of waste disposal.

Arguments: *Input*
CF, CNDXVP, IVCOST, MAREM, MSREM, SOLWST, SO2DV, WFGDSW

Output
VCWAST

Method: Goes to the correct section of code depending on the SO$_x$ device in place and, for wet FGD, a user specified switch. Returns to scale models are used.

6.4.2.50 Subroutine WSR

Task: Calculates the weight stoichiometric ratio for scrubber sludge.

Arguments: *Input*
SO2DV, SO2REM, MSRLMB

Output
WSR

Method: Goes to the correct section of code depending on the SO$_2$ device.

6.5 Flowcharts of Principal Subroutines

Figures C6-7 through C6-17 are flowcharts for eleven major subroutines: ALTCOL, ALTER, BLEND, CNTRL, DISPSL, EMITRT, FGDCST, NOXBLD, PCTLGO, TSPBLD, and TSPCST.

6.6 Variable Definitions

Table C6-3 gives short descriptions of the variables used in the pollution control module, while Table C6-4 gives detailed information about these variables.

Figure C6–7
ALTCOL FLOWCHART

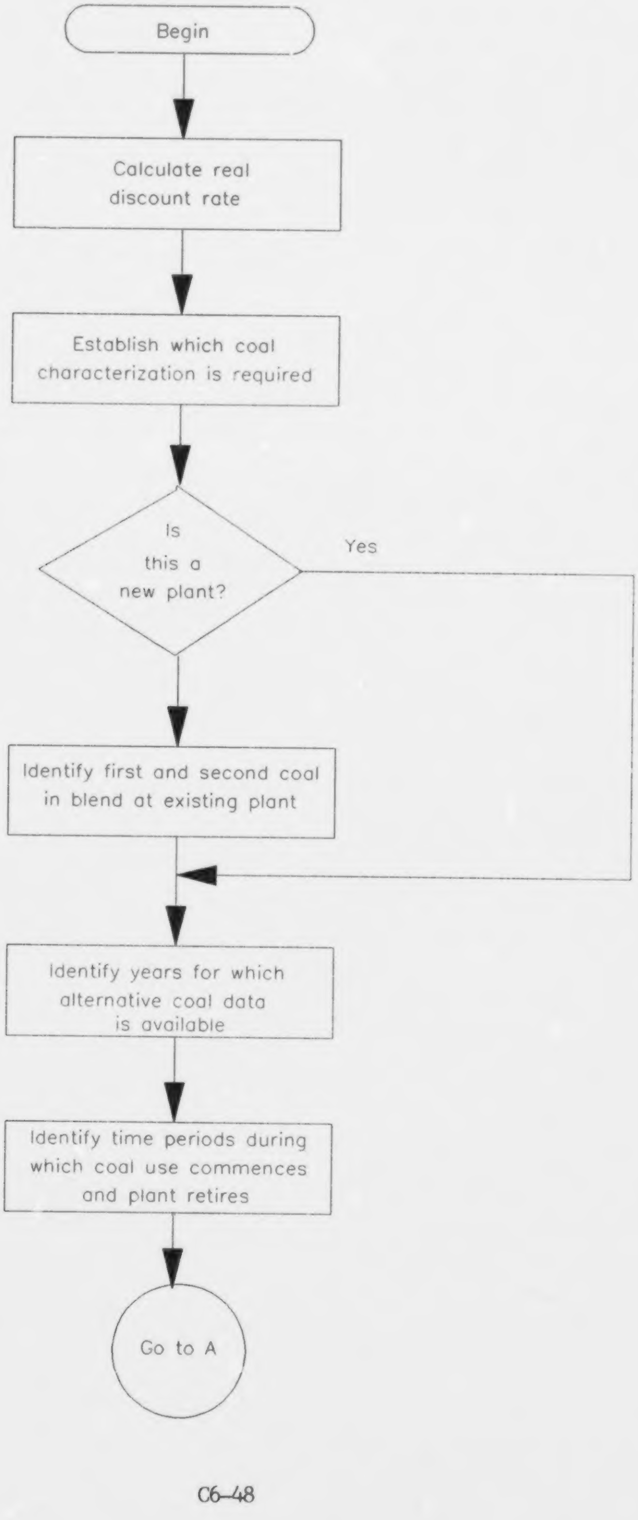

Begin
Calculate real discount rate
Establish which coal characterization is required
Is this a new plant?
Yes
Identify first and second coal in blend at existing plant
Identify years for which alternative coal data is available
Identify time periods during which coal use commences and plant retires
Go to A

Figure C6–7 (contd.)

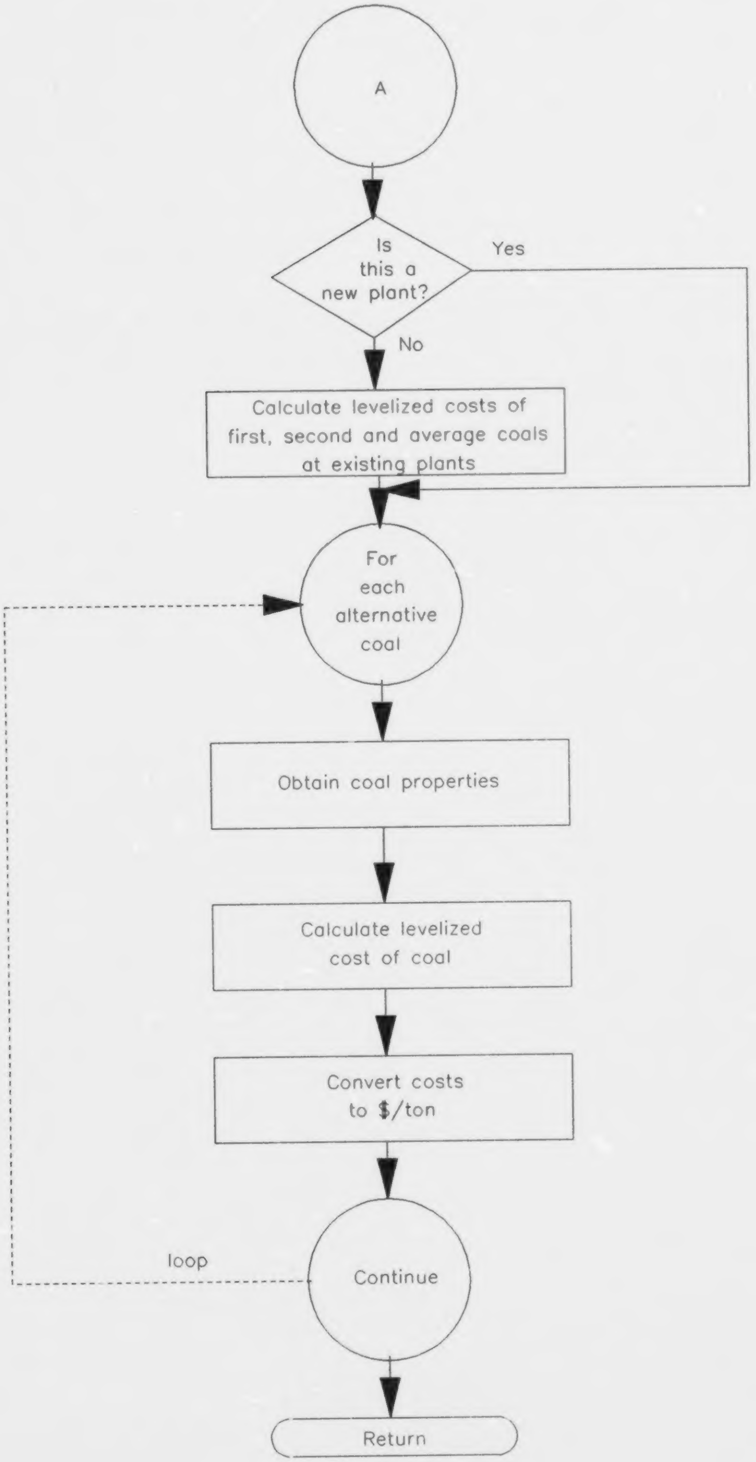
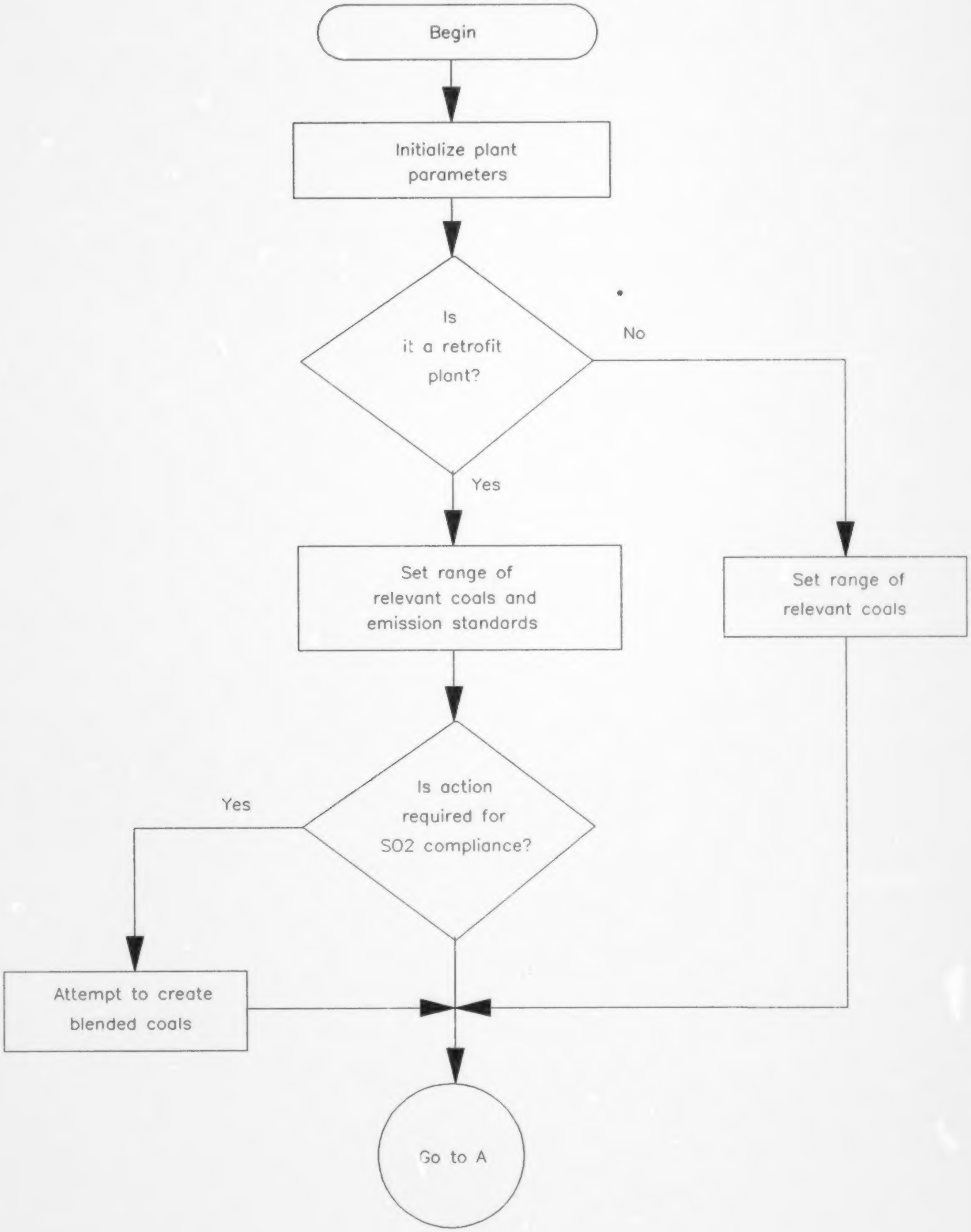

A
Is this a new plant?
Yes
No
Calculate levelized costs of first, second and average coals at existing plants
For each alternative coal
Obtain coal properties
Calculate levelized cost of coal
Convert costs to $/ton
loop
Continue
Return

Figure C6–8
ALTER FLOWCHART


Begin
Initialize plant parameters
Is it a retrofit plant?
No
Yes
Set range of relevant coals and emission standards
Set range of relevant coals
Is action required for SO2 compliance?
Yes
Attempt to create blended coals
Go to A

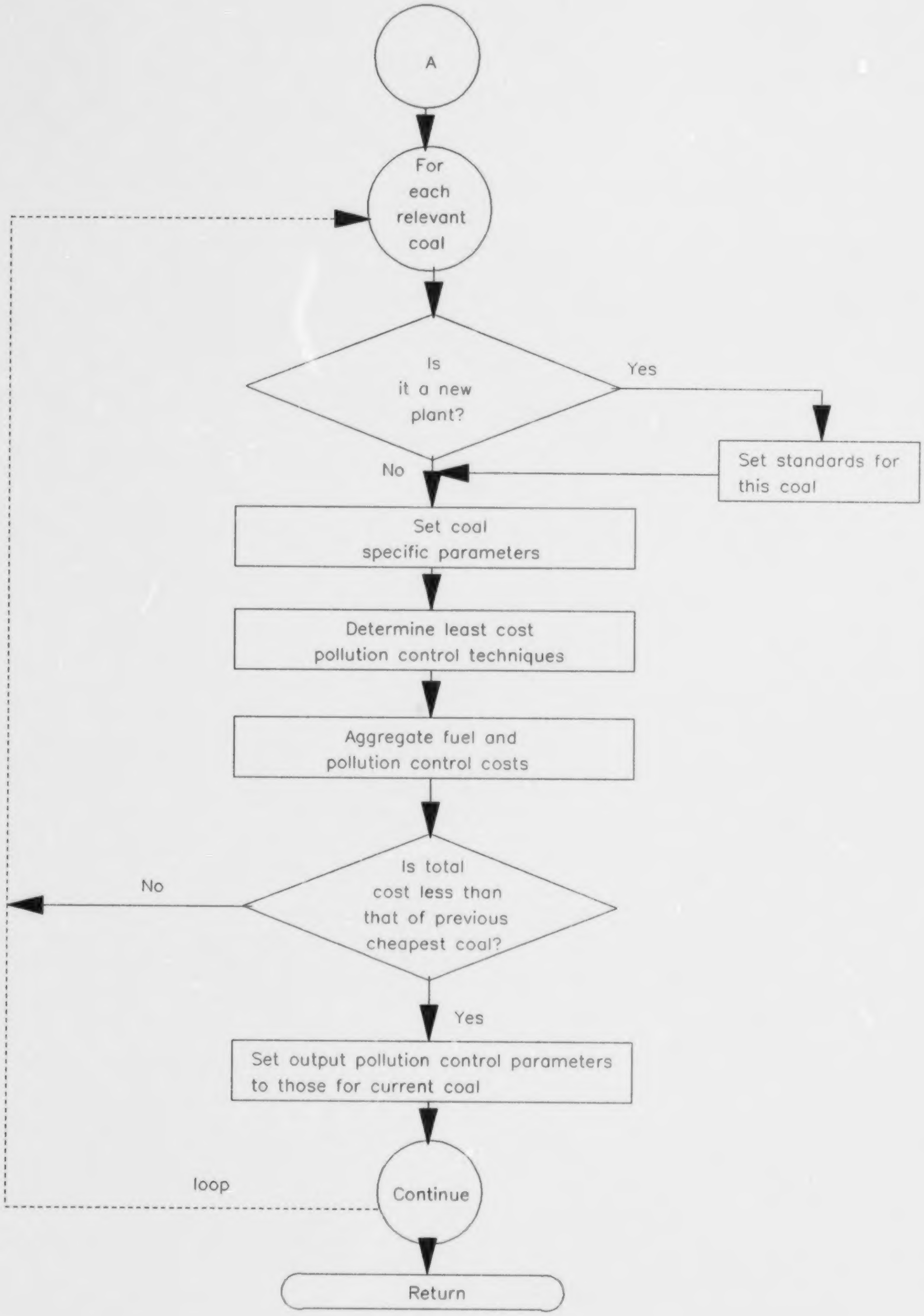

A
For each relevant coal
Is it a new plant?
Yes
Set standards for this coal
No
Set coal specific parameters
Determine least cost pollution control techniques
Aggregate fuel and pollution control costs
Is total cost less than that of previous cheapest coal?
No
Yes
Set output pollution control parameters to those for current coal
loop
Continue
Return

Figure C6–8 (contd.)

Figure C6-9
BLEND FLOWCHART

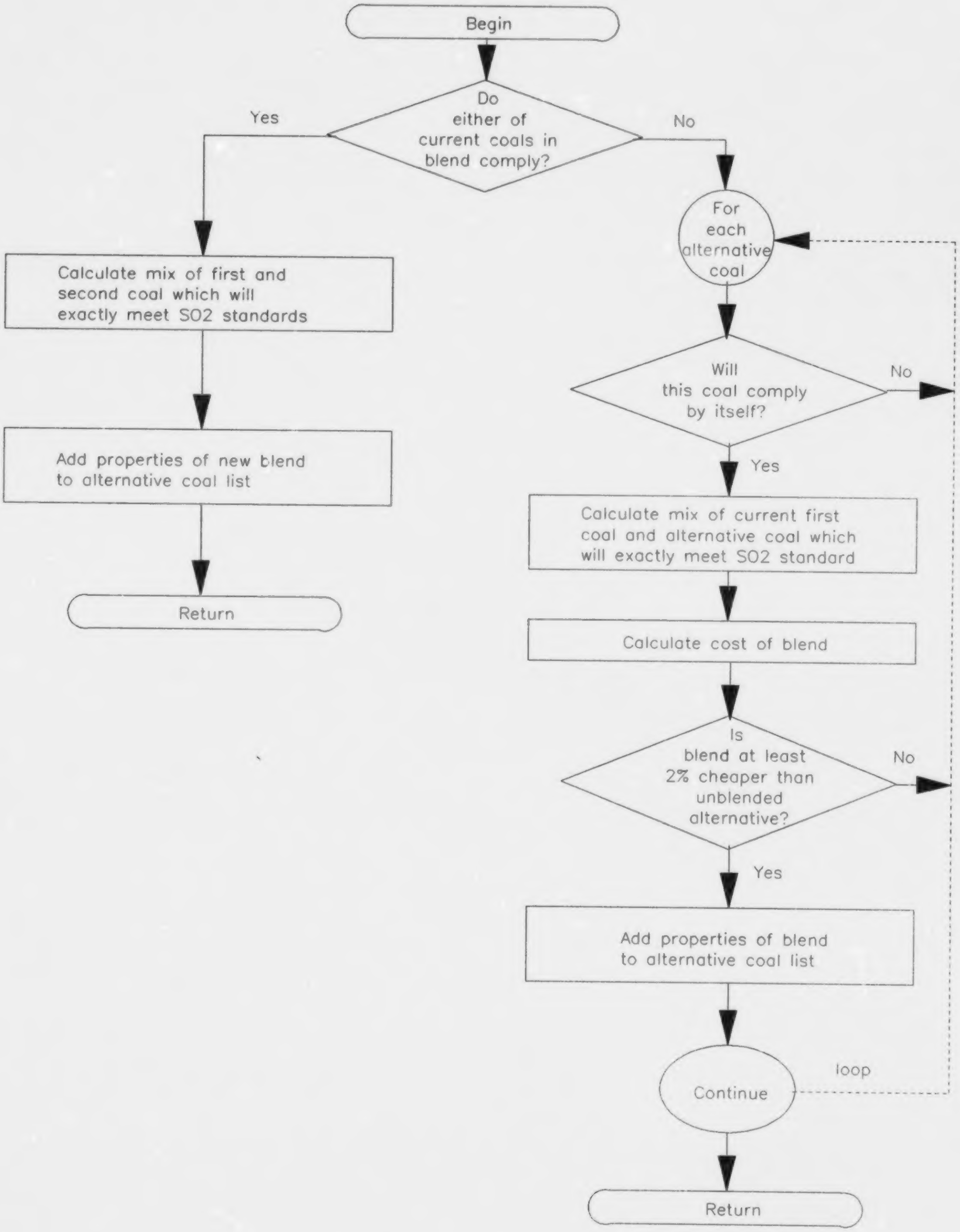

Begin
Do either of current coals in blend comply?
Yes
No
Calculate mix of first and second coal which will exactly meet SO2 standards
Add properties of new blend to alternative coal list
Return
For each alternative coal
Will this coal comply by itself?
No
Yes
Calculate mix of current first coal and alternative coal which will exactly meet SO2 standard
Calculate cost of blend
Is blend at least 2% cheaper than unblended alternative?
No
Yes
Add properties of blend to alternative coal list
Continue
loop
Return

Figure C6–10
CNTROL FLOWCHART

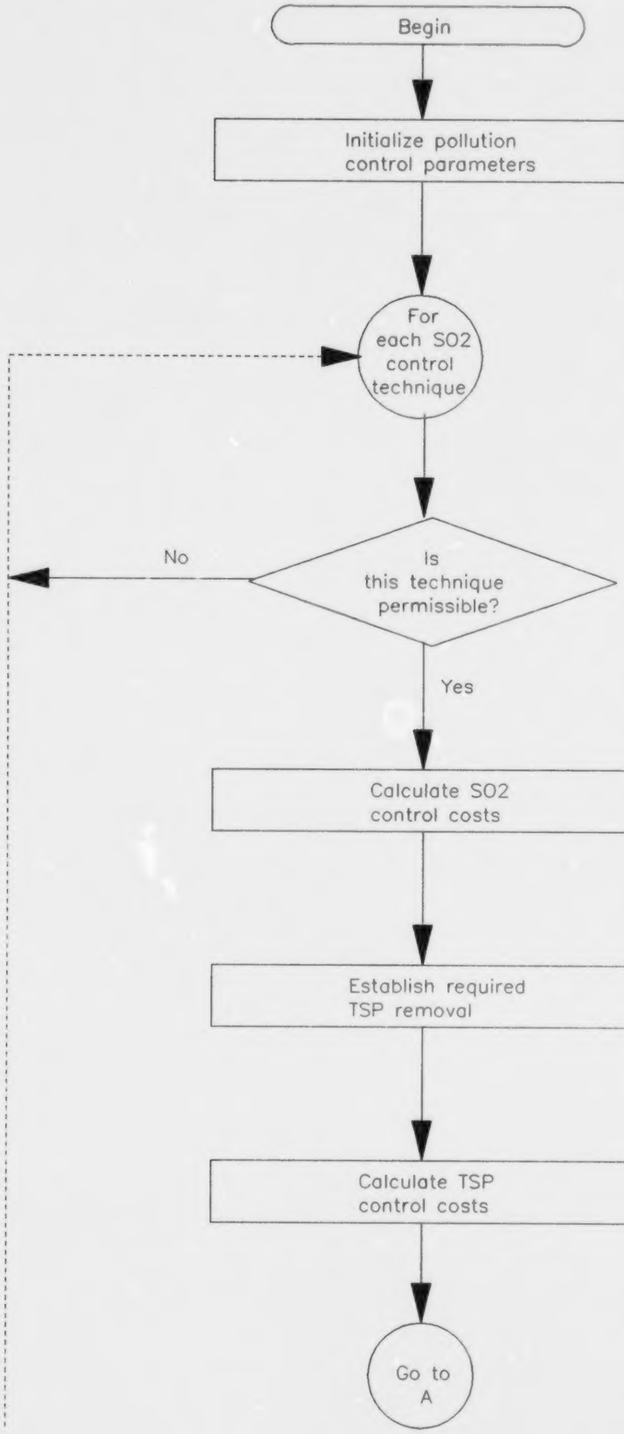

Begin
Initialize pollution control parameters
For each SO2 control technique
Is this technique permissible?
No
Yes
Calculate SO2 control costs
Establish required TSP removal
Calculate TSP control costs
Go to A

Figure C6-10 (contd.)

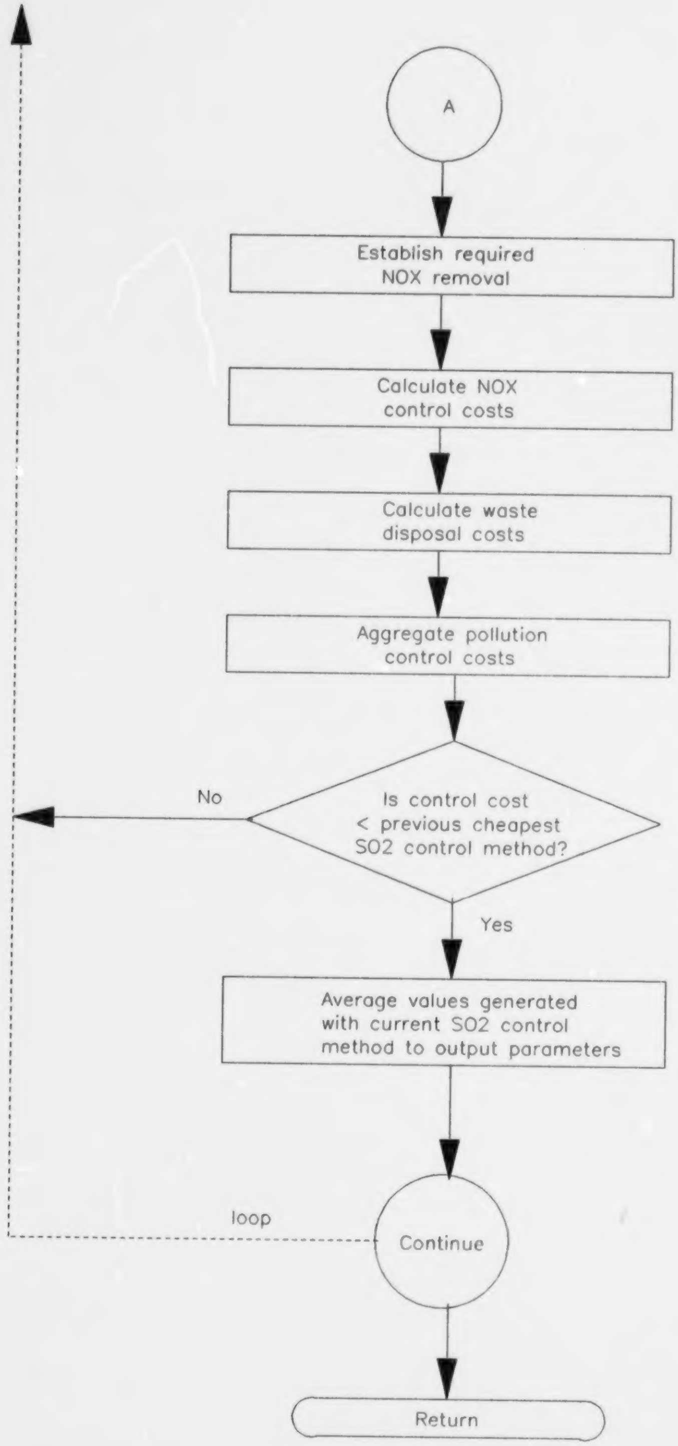

A
Establish required NOX removal
Calculate NOX control costs
Calculate waste disposal costs
Aggregate pollution control costs
Is control cost < previous cheapest SO2 control method?
No
Yes
Average values generated with current SO2 control method to output parameters
loop
Continue
Return

Figure C6-11
DISPSL FLOWCHART

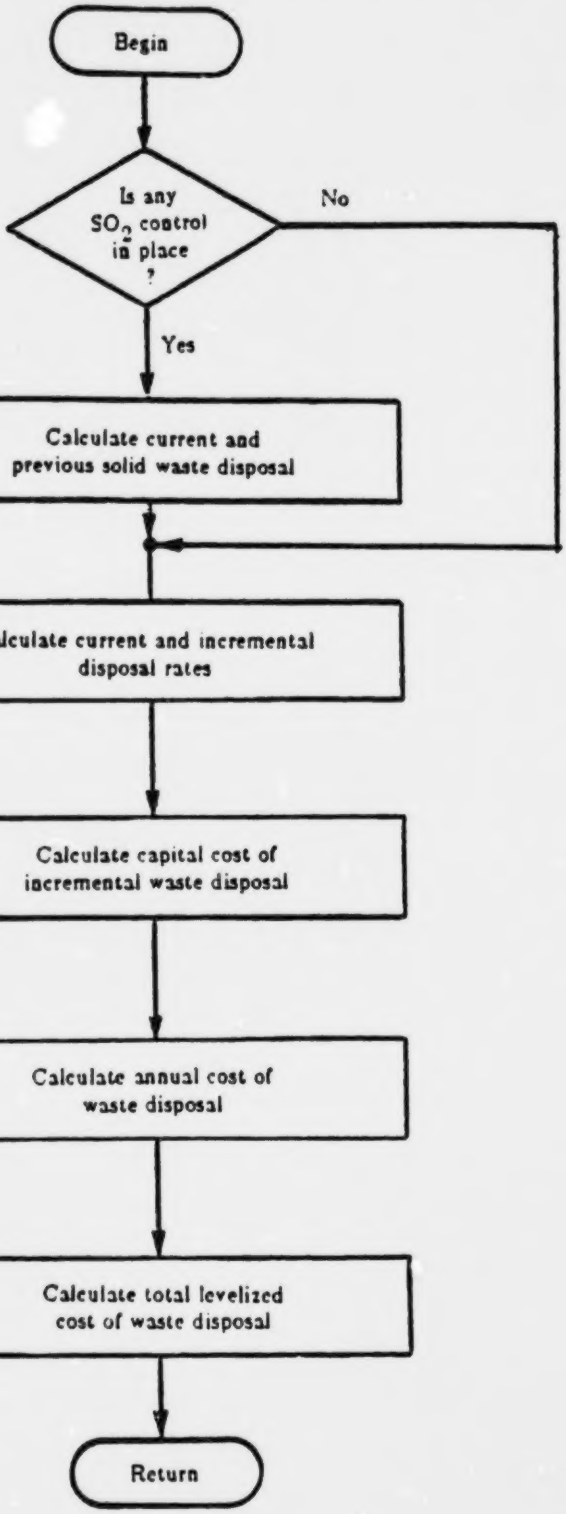

Begin
Is any SO_2 control in place ?
No
Yes
Calculate current and previous solid waste disposal
Calculate current and incremental disposal rates
Calculate capital cost of incremental waste disposal
Calculate annual cost of waste disposal
Calculate total levelized cost of waste disposal
Return

Figure C6-12

EMITRT FLOWCHART

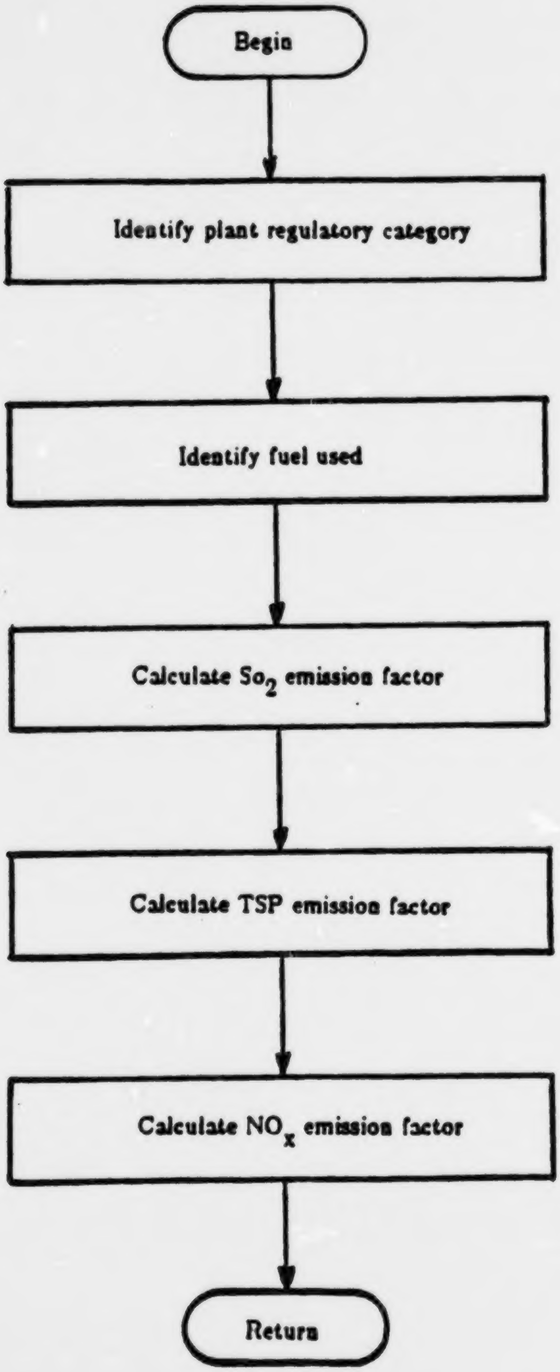

Begin
Identify plant regulatory category
Identify fuel used
Calculate So_2 emission factor
Calculate TSP emission factor
Calculate NO_x emission factor
Return

Figure C6-13
FGDCST FLOWCHART

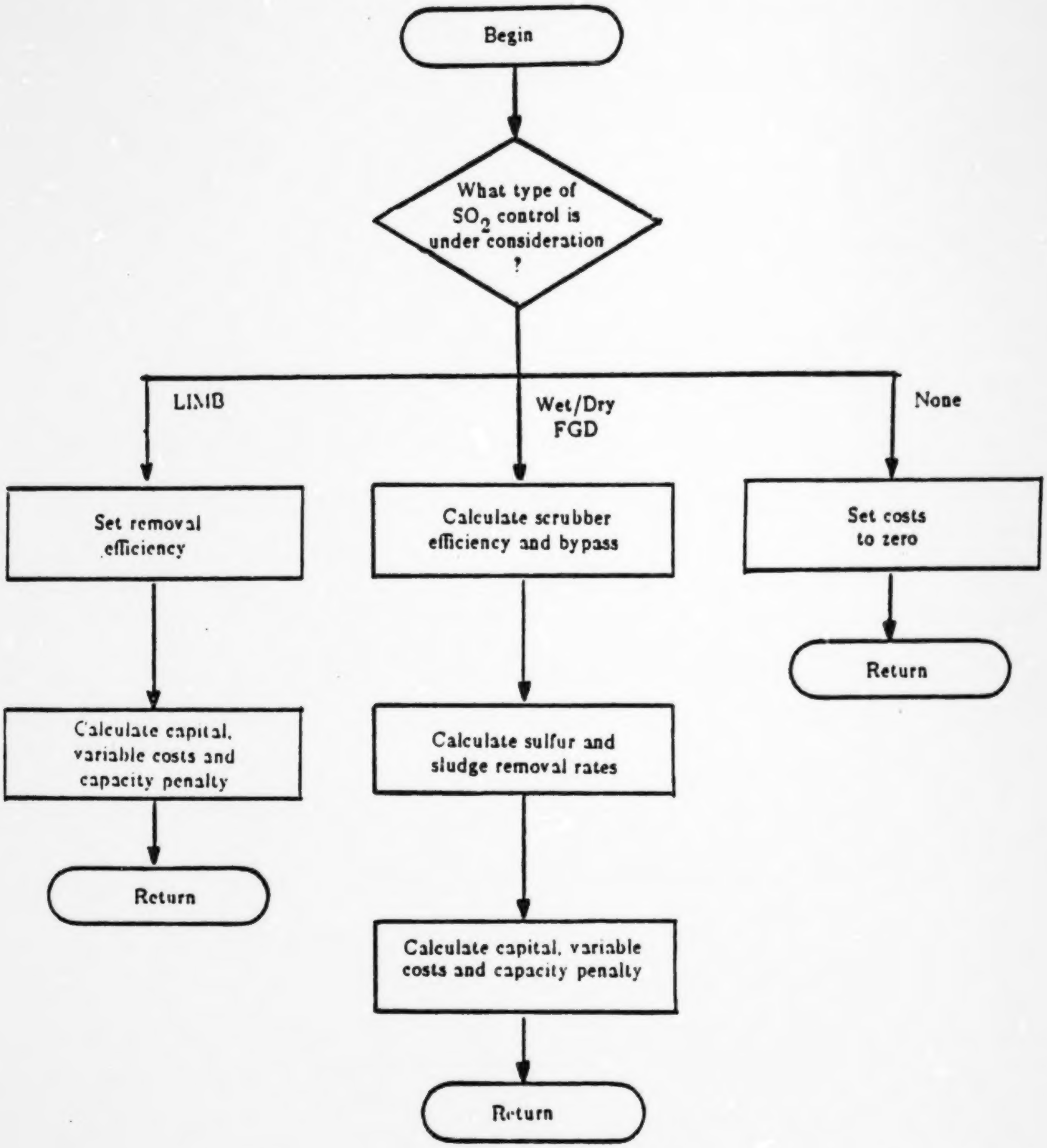

Begin
What type of SO_2 control is under consideration ?
LIMB
Wet/Dry FGD
None
Set removal efficiency
Calculate capital, variable costs and capacity penalty
Return
Calculate scrubber efficiency and bypass
Calculate sulfur and sludge removal rates
Calculate capital, variable costs and capacity penalty
Return
Set costs to zero
Return

Figure C6-14
NOXBLD FLOWCHART

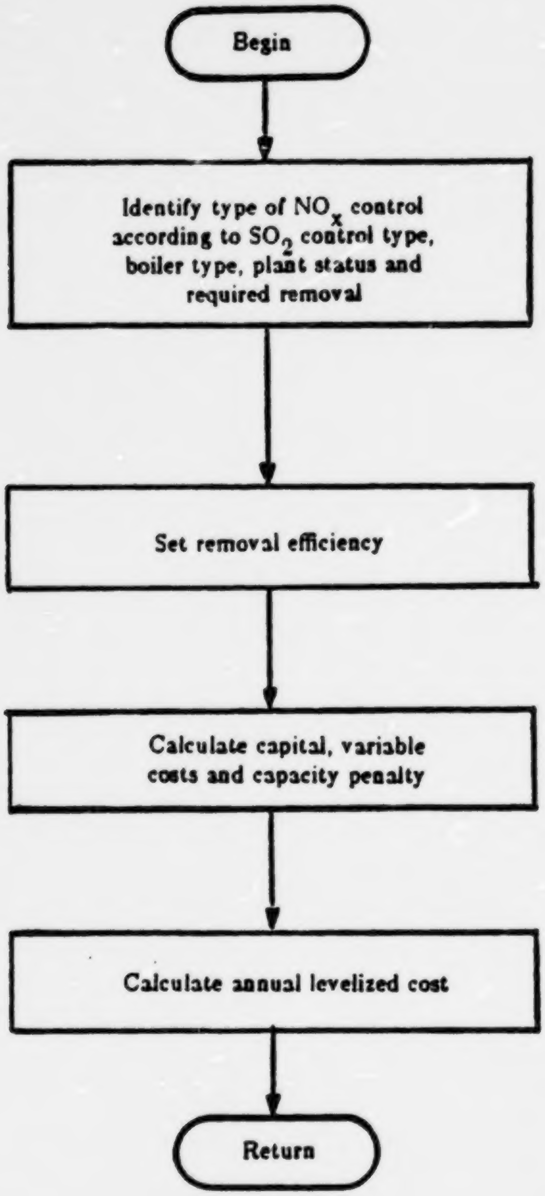
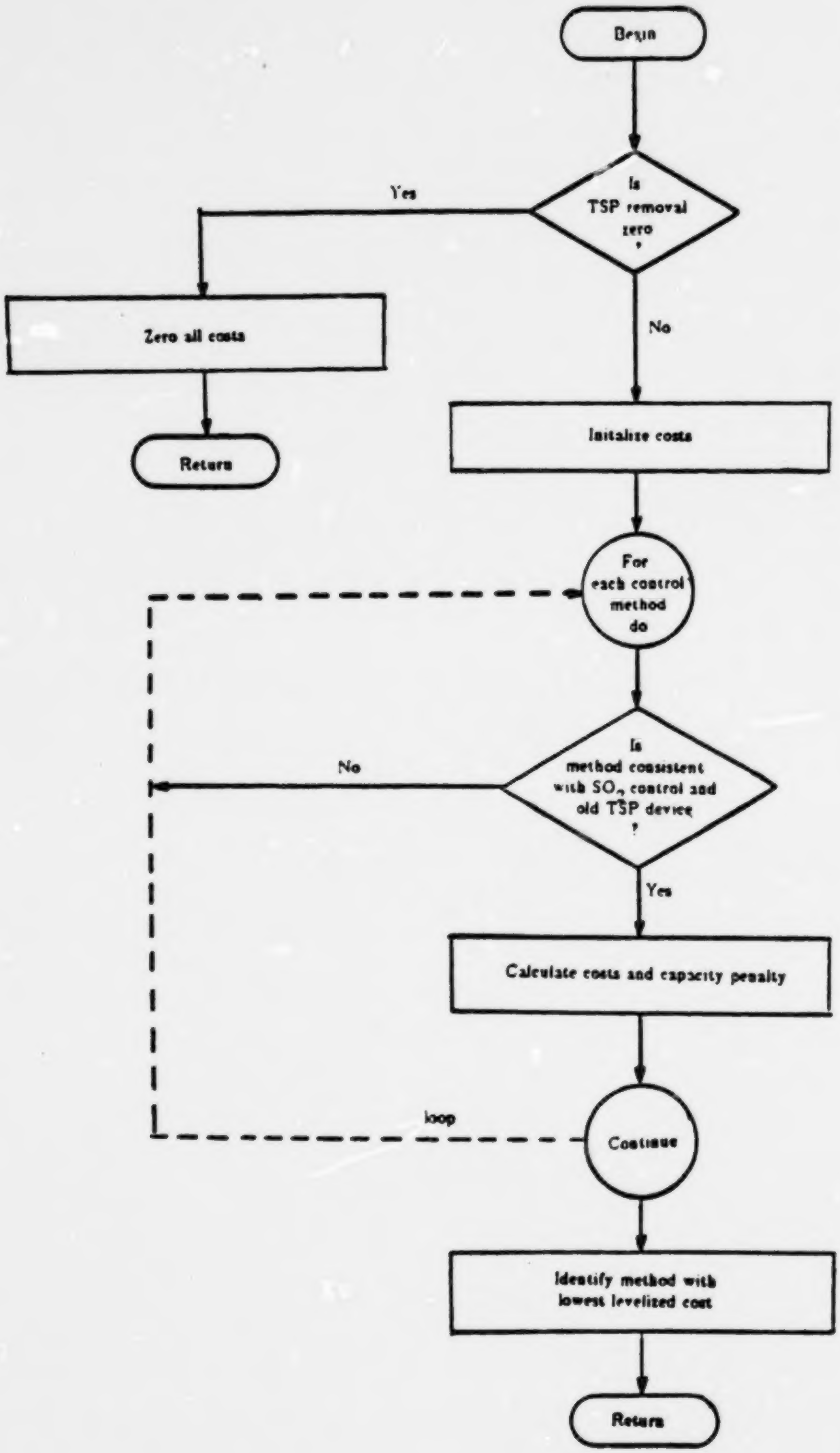

Begin
Identify type of NOx control according to SO2 control type, boiler type, plant status and required removal
Set removal efficiency
Calculate capital, variable costs and capacity penalty
Calculate annual levelized cost
Return

Figure C6-15

TSPBLD FLOWCHART



Begin
Is TSP removal zero ?
Yes
Zero all costs
Return
No
Initalize costs
For each control method do
Is method consistent with SO₂ control and old TSP device ?
No
Yes
Calculate costs and capacity penalty
loop
Continue
Identify method with lowest levelized cost
Return

Figure C6–16
PCTLGO FLOWCHART

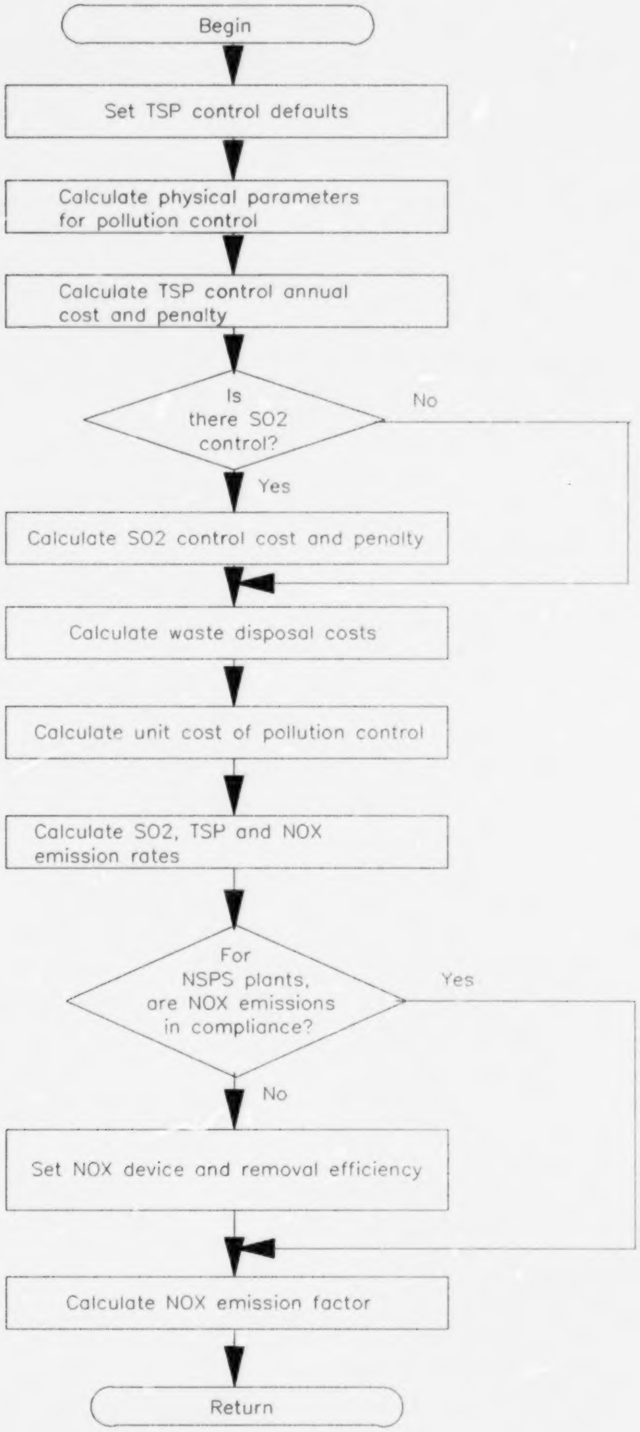

Begin
Set TSP control defaults
Calculate physical parameters for pollution control
Calculate TSP control annual cost and penalty
Is there SO2 control?
No
Yes
Calculate SO2 control cost and penalty
Calculate waste disposal costs
Calculate unit cost of pollution control
Calculate SO2, TSP and NOX emission rates
For NSPS plants, are NOX emissions in compliance?
Yes
No
Set NOX device and removal efficiency
Calculate NOX emission factor
Return

Figure C6-17
TSPCST FLOWCHART

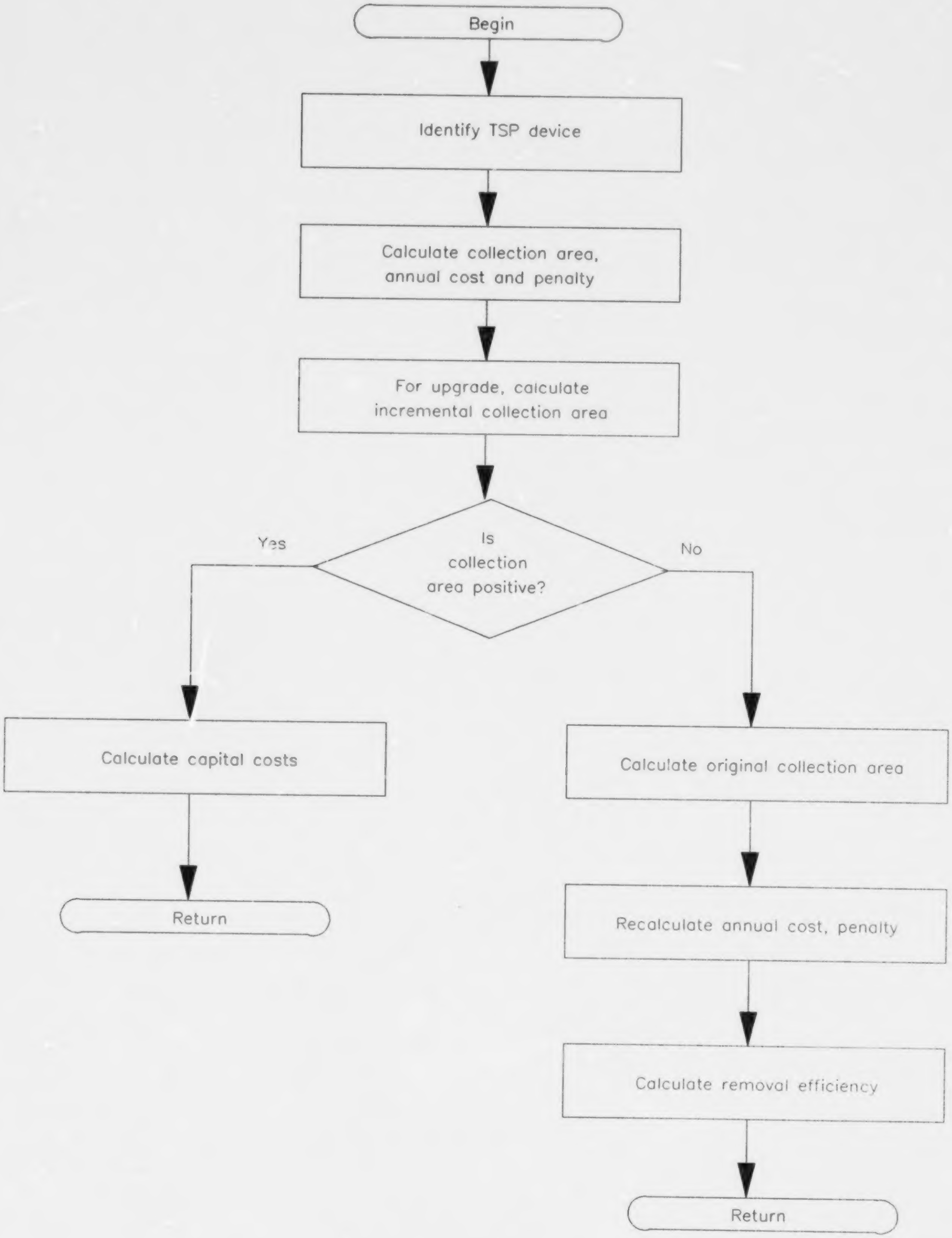

Begin
Identify TSP device
Calculate collection area, annual cost and penalty
For upgrade, calculate incremental collection area
Is collection area positive?
Yes
No
Calculate capital costs
Return
Calculate original collection area
Recalculate annual cost, penalty
Calculate removal efficiency
Return

Table C6-3
VARIABLE DESCRIPTIONS

Variable	*Units*	*Description*
ACCCST	$	Accumulated capital cost (in nominal $) over a construction schedule
ACTTEM	Degrees Rankine	Actual stack temperature.
ADJUST		Adjustment to gas-flow rate for cash and moisture content
ADVLRM	Fraction	Annual *ad valorem* charges for capital invested.
ALTFUL	Cents/MMBtu	Default prices of fuels other than coal.
ASH1	Fraction	Ash content of first coal in blend.
ASH2	Fraction	Ash content of second coal in blend.
ASH	Fraction	Ash content of coal.
ASHN	Fraction	Ash content of the new coal.
ASHO	Fraction	Ash content of the old coal.
ASHRET	Fraction	Ash retention of coal sulfur for bituminous, sub-bituminous and lignite coals.
AVEOIL		Use for data transfer of oil characteristics
AVGTMS		(1) Pointer to averaging time used in calculation of coal sulfur relative standard deviation (RSD) for SIP units (defined as those online prior to 1972). (2) Pointer to averaging time used in calculation of coal sulfur relative standard deviation (RSD) for NSPS units (defined as those online after 1971). Valid options are: 1 which implies 1 day averaging time 2 which implies 30 day averaging time 3 which implies 365 day averaging time
BAGCST	$/sq ft	Fabric filter bag replacement cost.
BAGLIF	Years	Lifetime of bag filter.
BAGRC	$/yr	Annual cost of bag filter replacement.

Table C6-3 (contd.)

Variable	*Units*	*Description*
BLCOST	$/ton	Cost of blended coal.
BLEND		Logical variable set to true if a blend is selected.
BLHHV	Btu/lb	Higher heating value of blended coal.
BOLTYP	Codelist H	Boiler (firing) type.
BOTTYP	Codelist G	Boiler bottom type.
BOUND1	Lbs/MMBtu	SO_2 content of coal signifying boundary between upper removal regime and upper cap regime in RNSPS.
BOUND2	Lbs/MMBtu	Boundary between upper removal and lower cap regimes.
BOUND3	Lbs/MMBtu	Boundary between lower removal and lower cap regimes.
BtuFR1	Fraction	Btu fraction of first coal in a blend.
BtuFRC	Fraction	Btu fraction of a coal in a blend.
Btu1	Fraction	Btu fraction of first coal in blend.
Btu2	Fraction	Btu fraction of second coal in blend.
BtuYR	10^9Btu/yr	Average coal consumption in current year.
BtuYR1	10^9Btu/yr	First coal consumption in current year.
BtuYR2	10^9Btu/yr	Second coal consumption in current year.
BYPASS	Fraction	FGD bypass fraction.
BYPSSC	Fraction	Temporary bypass fraction storage.
BYPSSO	Fraction	Old bypass fraction.
C	-	Used for calculating escalation rate.
CAPAVG	Tons/hr	Average rate of sludge removal from a scrubber.
CAPAVG	Tons/hr	FGD reagent capacity based upon average sulfur content of coal.
CAPCOS	$	Capital cost.

Reproduced from best available copy.

Table C6-3 (contd.)

Variable	*Units*	*Description*
CAPFAC	Fraction	Current plant capacity factor.
CAPFGD	MW	Capacity penalty of SO_2 control device.
CAPPEN	MW	Plant capacity penalty.
CAPPNC	MW	Capacity penalty passed from SWITCH.
CAPRSD	Tons/hr	Peak sludge removal rate from scrubber.
CCESC	Fraction	Capital cost escalation factor.
CCFACT		Used to escalate capital costs above their 1980 value.
CCFGDC	$	Temporary capital cost FGD storage.
CCNOXC	$	Temporary NO_x control capital cost storage
CCTSP	$	Capital cost of a TSP control device.
CCTSPC	$	Capital cost of TSP control passed from CNTROL.
CCTSPC	$	Temporary capital cost TSP control storage.
CCUPGR	$/KW	Unit capital cost of a scrubber upgrade.
CCWSTC	$	Temporary capital cost waste disposal storage.
CF	Fraction	Plant capacity factor based on plant age.
CLTYP1		Type of first coal in blend.
CLTYP2		Type of second coal in blend.
CNDXCP		Chemical engineering construction cost index.
CNDXVP		Variable cost index.
COAL		Index for coal under consideration (references COALS).
COALM	Tons/day	Peak rate of plant coal use.
COALMN	Tons/day	New peak rate of plant coal use.
COALMO	Tons/day	Former peak rate of plant coal use.

Table C6-3 (contd.)

Variable	*Units*	*Description*
COALS		Array of alternative coal properties.
		COAL(I, J)
		I = Coal Index
		1. First Coal in blend
		2. Second coal in blend
		3. Average coal
		J = characteristic index
	Fraction	1. sulfur fraction
	Fraction	2. ash fraction
	Btu/lb	3. higher heating value
	Cents/MMBtu	4. levelized cost
	$/year	5. system cost
	Codelist M	6. preparation code
	Fraction	7. sulfur fraction adjusted for variability
	Codelist J	8. supply region code
	Cents/MMBtu	9. present coal cost
	Fraction	10. Btu fraction of this coal used in a blend
	Fraction	11. sulfur fraction adjusted for ash retention
COALVC	$/year	Annual cost of using a coal.
COALYR	Tr Btu/year	Annual coal use in state.
COLADJ	Fraction	Sulfur content of coal adjusted for ash sulfur retention.
COLASH	Fraction	Ash fraction in coal.
COLBTU	Btu/lb	Coal higher heating value.
COLCLE		Index indicating whether coal is cleaned 0 = no, 1 = yes
COLDAT		Coal properties corrESPonding to entries 24 - 47 in data group 70.
COLHHV	Btu/lb	Coal higher heating value.
COLRSD	Fraction	Sulfur fraction adjusted for variability.
COLSUL	Fraction	Sulfur fraction of coal.
COLTYP	-	Coal type index: 1 = bituminous 2 = sub-bituminous 3 = lignite

Table C6-3 (contd.)

Variable	*Units*	*Description*
CONTIM	Years	Pollution control device construction time.
COST	$	Present value of a stream of capital costs.
CPNOXC	MW	Temporary NO_x control capacity penalty storage.
CPRSDN	Tons/hr	FGD reagent capacity based upon coal sulfur RSD for new SO_2 standard.
CPRSDO	Tons/hr	FGD reagent capacity based upon coal sulfur RSD for existing SO_2 standard.
CPTSPC	MW	Temporary TSP control capacity penalty storage.
CURBBL	$	Price per barrel of oil
CTNATL		Array containing all the pollution control constants from data group 30.
CURCOS	$/yr	Annual cost of coal plus pollution control.
CUREMM	Lbs/MWh	SO_2 emissions from oil-fired unit
CURHHV	Btu/gal	Heating value of oil
CURPRC	Cents/MMBtu	Oil price
CURSUL	Fraction	Oil sulfur content
CWIP	$	Construction work in progress accumulated after a construction schedule.
DCCMAT	$	Direct capital cost of materials handling and preparation for scrubbers.
DCCSCR	$	Direct capital cost of scrubber.
DEFSO2	Fraction	Default SO_2 removal fraction.
DEPLTN	1000 tons/yr or 1000 MMBtu/yr	Coal shipments in current year
DEPREC	$	Present value of the depreciation allowances on $1 of investment.
DESSUL	Fraction	Required SO_2 removal.

Table C6-3 (contd.)

Variable	*Units*	*Description*
DEVCON	Years	Construction time for a pollution control device.
DEVEXP	Fraction	Construction schedule of a pollution control device.
DEVTYP	-	Code for type of pollution control: 1 = SO_2 control 2 = TSP/waste 3 = NO_x
DFSO2D	Fraction	Default dry FGD SO_2 removal efficiency.
DFSO2W	Fraction	Default wet FGD SO_2 removal efficiency.
DISCNT	Fraction	Nominal interest rate.
DLNCST	$/acre	Default land cost for FGD sludge disposal.
DNMNTR		Constraint for calculating blend fractions.
DRYFGD		Various cost parameters for dry FGD.
DRYSW	-	Switch for dry FGD 0 = excluded 1 = permitted
DRYTEM	Degrees Rankine	Gas temperature after dry scrubber.
DRYYR		Year from which dry FGD is permitted.
DUM1		Dummy variable passed from OILSWH to EMITRT.
DUM2		Dummy variable passed from OILSWH to EMITRT
EFCOAL	Ton emission/ ton coal	Emission factors for uncontrolled conventional coal-fired utility boilers. 1 NO2–General boilers 2 NO2–Wet bottom boilers 3 NO2–Dry bottom boilers 4 NO2–Cyclone boilers 5 NO2–Spreader stoker boilers 6 NO2–Dry bottom boilers (lignite) 7 NO2–Wet bottom/front firing (lignite) 8 NO2–Wet bottom/tangential (tangential) 9 NO2–Cyclone boilers (lignite) 10 NO2–Spreader stoker boilers (lignite)

Table C6-3 (contd.)

Variable	*Units*	*Description*
EFGAS	Ton emission/ MSCF gas	Emission factors for uncontrolled gas-fired utility boilers. 1 SO2 2 TSP 3 NO2–General boilers 4 NO2–Tangentially fired boilers
EFOIL	Lb emission/ th gal oil	Emission factors for uncontrolled oil-fired utility boilers. 1 SO_2 (multiply by the percent sulfur in the oil) 2 TSP (fixed) 3 TSP (variable with sulfur) 4 NO2–General boilers 5 NO2–Tangentially fired boilers
ELCLVL		Levelization factor for electric power cost.
ELECT	MW	FGD capacity penalty, electric power component.
ELECYR	$/year	Annual cost of electric power lost by capacity penalty.
ELRVNU	$/MWh	Default cost of alternative power generation for costing costing capacity penalties.
EMRATE	Lbs/MMBtu	Emission rate.
ENERGY	GWh	Electricity dispatched from a plant annually.
ESC	Fraction	Coal price escalation rate.
ESC1	Fraction	Escalation rate in previous time period.
ESC2	Fraction	Escalation rate in next time period.
ESCAL		Real annual escalation factor.
ESPEFF	Fraction	TSP control device efficiency.
ESPUGC	$/KW	Unit capital cost for cold ESP upgrade
ESPUGV	mills/KWh	Unit variable cost for cold ESP upgrade
EXAIR	Fraction	Excess combustion air. (First element only)
EXMLTS	Fraction	Multiplier for sulfur RSD calculation. Options: Value Conditions

Table C6-3 (contd.)

Variable	*Units*	*Description*
		2. exemption of 75% removal for three days. 3. no SO_2 emission exemptions. 3. 30 day averaging time. 0 none of above apply (this will make the sulfur RSD equal to the average coal sulfur).
EXPSCH	Fraction	Expenditure schedule for a pollution control device.
FABAC	ACFM/sq ft	Fabric filter air-to-cloth ratio.
FABACO	ACFM/sq ft	Old fabric filter air-to-cloth ratio.
FABAR	Sq ft	Fabric filter cloth area.
FACTOR		Ratio of interest rate factor to cost escalation factor.
FCTR1	-	Discounting factor for calculating CWIP during construction schedule.
FCTR2	-	Discounting factor for calculating ACCCST during construction schedule.
FGDCON	Years	FGD construction time.
FGDEXP	Fraction	Expenditure schedule for FGD construction.
FGDG	ACFM	Gas flow through scrubber.
FGDGEN	MW	Scrubber size.
FGDMIN	MW	Minimum FGD size.
FGDPEN	MW	FGD capacity penalty.
FGDSLG	Tons/year	FGD sludge disposal rate.
FLYASH	Fraction	Fraction of ash converted to flyash.
FRAC1	Fraction	Weight fraction of first coal in a blend.
FRAC2	Fraction	Weight fraction of second coal in a blend.
FTYPE	Codelist H	Firing type.
FUELYR	Trillion Btu/yr	Plant fuel use.

Table C6-3 (contd.)

Variable	*Units*	*Description*
FXCHFC	Fraction	Fixed charge factor for annualizing a capital cost.
G	ACFM	Peak gas flow rate at a plant.
GASYR	Trillion Btu/yr	Annual gas use.
GEN	MW	Plant capacity.
GHOT	ACFM	Peak gas flow rate through hot ESP device.
GRSGEN	MW	Gross (initial) capacity at a plant.
HEATRT	Btu/KWh	Plant heat rate.
HHV	Btu/lb	Higher heating value.
HHV1	Btu/lb	Higher heating value of first coal in blend.
HHV2	Btu/lb	Higher heating value of second coal in blend.
ICCOST		Cost factor used to escalate capital costs from 1980 level.
ICF		Indirect cost factor for construction costs.
ICFLF		Indirect cost factor for landfill.
ICFPND		Indirect cost factor for ponding.
ICLEN		Code indicating whether coal is cleaned.
ICMPLY	Year	Compliance year for plant.
ICOLCT	-	Index for coal type used at plant. See COALTYP.
ICOLSZ		Number of alternative unblended coals for a plant plus two.
IDUMMY		Dummy variable in call to GET from LVLCST.
IDWAST		Index for solid waste disposal type - 1. untreated 2. chemical fixation 3. gypsum landfill
IDX	-	Index referring to alternative coals.

Table C6-3 (contd.)

Variable	*Units*	*Description*
IDX1	-	Index for coal price year.
IDX2	-	Index for coal price year.
IDXCL1	-	Index for coal price year.
IDXCL2	-	Index for coal type.
IDXCOL	-	Index for coal type.
IDXFLY	-	Index for flyash fraction.
IDXGET	-	Index for coal price year.
IDXNOW	-	Index for coal price year.
IDXNOX	-	Stage of NO_x control device construction.
IDXNXT		Index used for accessing coal price data.
IDXOFF	-	Index for coal price year.
IDXON	-	Index for coal price year.
IDXSO2		Stage of scrubber construction.
IDXTSP		Stage of TSP control device construction.
IFCODE	Codelist C	Fuel type.
IGT20	-	Item list for getting DG20.
IGT60	-	Item list for getting DG60.
IGT61	-	Item list for getting DG61.
IGTAVR		Item list for getting average fuel data from the Unit Inventory File.
IGTCOL		Item list for getting fuel data from Unit Inventory.
IGTNEW		Item list for getting new unit data.
IGTOIL		Item list for reading oil characteristics.
IGTRTR		Item list for getting regulatory data from Unit Inventory.

Table C6-3 (contd.)

Variable	*Units*	*Description*
IGTTX		Item list for obtaining tax depreciation schedule.
IGTXST		Item list for getting plant data from the Unit Inventory.
INFLAT	Fraction	Inflation rate.
INOXCP	-	Stage of NO_x control device construction.
INTCST	Cents/MMBtu	Initial coal price.
IPT32		Item list for creating a new entry in the retrofit files.
IPTALT		Item list for putting fuel data to the Unit Inventory.
IPTCON		Item list for adding data to the construction schedule for new units.
IPTINT		Item list for putting initial pollution control data to the Unit Inventory.
IPTNEW		Item list for putting new unit data to the Unit Inventory.
IPTOIL		Item list for putting new oil characteristics to the Unit Inventory File.
IPTRTR		Item list for putting retrofit data to the Unit Inventory.
IPTXST		Item list for putting new coal data to the Unit Inventory.
IRID		Report identification number.
IRID80		Report identification number.
IRTRO		Index for retrofit construction schedule entries.
ISO2CP	Year	SO_2 compliance year.
ISTATE	Codelist I	State code.
ISTOP		Argument passed to subroutine ERROR.
ISUB		Report subheading number.

Table C6-3 (contd.)

Variable	*Units*	*Description*
ISUB80		Report subheading number.
ISUPPL	Codelist J	Coal supply region.
IT1		Used for creating new elements in retrofit files.
ITC	$	Investment tax credit.
ITCELG	Fraction	Investment tax credit eligibility.
ITCHCD	Codelist B	Plant technology code.
ITCHFC		Code cross-referencing technologies and fuels.
ITCRAT	Fraction	Investment tax credit rate.
ITMP		Supply region.
ITMS		Integer equivalent of AVGTMS.
ITRACE		Trace level.
ITSPCP		Stage of TSP device construction.
IUNSEQ		Unit sequence number in data group 70.
IVCOST		Variable cost escalation multiplier.
IYEAR	Year	Current year of simulation.
IYRDCD	Year	Year in which pollution control strategy must be decided.
JCAT		Coal supply region.
JH1		Coal type.
JH2		Coal type.
KS		Coal supply region.
LAND	$/acre	Cost of land for waste disposal.
LEAD	Years	Lead time for bringing on pollution control equipment.
LIFCST	Cents/MMBtu	Levelized cost of a coal.

Table C6-3 (contd.)

Variable	*Units*	*Description*
LIFE	Years	Default period for appraising pollution control equipment.
LIMB		Various cost parameters for LIMB technology.
LIMBSW	-	Switch for LIMB: 0 = excluded 1 = permitted
LIMBYR		Year from which LIMB technology is permitted.
LMSTR1		Limited SO_2 compliance strategy.
LMSTR2		Limited SO_2 compliance strategy.
LMSTR3		Limited SO_2 compliance strategy.
LNR	Log (ohm-cm)	Logarithm of flue gas resistivity in electrostatic precipitator.
LVLCOS	$/year	Annual levelized cost.
LVLCSC	$/year	Levelized cost of pollution control at plant.
LVLNOX	$/year	Levelized cost of NO_x control.
LVLTSP	$/year	Annual levelized cost of TSP control.
MAREM	Tons/hr	Ash removal rate.
MAREMI	Tons/hr	Incremental ash removal rate.
MAREMN	Tons/hr	New ash removal rate.
MAREMO	Tons/hr	Old ash removal rate.
MAX		Index for last coal to be examined.
MIN		Index for first coal to be examined.
MODCST	$	Direct capital cost of an individual scrubber train.
MPMSSW	-	Switch signals whether an EPOS run 0 = normal run 1 = MPMS run
MSR	-	Molar stoichiometric ratio for FGD reagent usage.

Table C6-3 (contd.)

Variable	*Units*	*Description*
MSREM	Tons/hr	SO_2 removal rate.
MSREMI	Tons/hr	Incremental SO_2 removal rate.
MSREMN	Tons/hr	New SO_2 removal rate.
MSREMO	Tons/hr	Old SO_2 removal rate.
MSREMP	Tons/hr	Peak SO_2 removal rate.
MSRLMB	-	Molar stoichiometric ratio for LIMB.
MST	Fraction	Moisture content of a coal.
MULT	-	Multiplier for small units.
NCOALS	-	Maximum number of coals to be examined.
NETGEN	MW	Unit capacity net of pollution control penalty.
NEWBBL	$/bbl	Price per barrel of a compliance oil.
NEWCOL		Index to new coal selected at a plant (references COALS).
NEWUN		Index to entry in retrofit construction schedules.
NHHV	-	Number of higher heating classes in a coal classification.
NHHVCT		Number of HHV categories for a coal categorization.
NMRTR		Construct for calculating blend fractions.
NOCOLS		Number of alternative coals (including blends) plus two.
NOHHV	-	As for NHHV.
NONEW		Number of units in construction schedule for new units (data group 23).
NOP		Number of operating scrubber trains.
NORTRO		Number of units in retrofit files (data groups 32 and 34).
NOSUL	-	Number of sulfur classes in a coal classification.

Table C6-3 (contd.)

Variable	*Units*	*Description*
NOXCOM		Logical variable indicating NO_x compliance.
NOXCON	Years	Construction period for NO_x control devices.
NOXCPC	Lbs/MMBtu	NO_x RNSPS cap for bituminous coal and lignite.
NOXCPG	Lbs/MMBtu	NO_x RNSPS cap for gas.
NOXCPO	Lbs/MMBtu	NO_x RNSPS cap for oil.
NOXCPS	Lbs/MMBtu	NO_x RNSPS cap for sub-bituminous coals.
NOXCYR	Tons/year	NO_x emissions from coal plants.
NOXDV	Codelist F	NO_x control device.
NOXDVC	Codelist F	NO_x control device.
NOXDVN	Codelist F	New NO_x control device.
NOXDVO		Old NO_x control device.
NOXEXP	Fraction	NO_x control device construction schedule.
NOXGYR	Tons/year	NO_x emissions from gas plants.
NOXLIM	Lbs/MMBtu	NO_x emission cap.
NOXLVL	$/year	Levelized cost of NO_x control.
NOXMWH	Lbs/MWh	NO_x emission factor.
NOXOYR	Tons/year	NO_x emissions from oil plants.
NOXPEN	MW	Capacity penalty for NO_x control.
NOXPMB	Lbs/MMBtu	NO_x emission level.
NOXREM	Fraction	NO_x removal.
NOXREQ	Fraction	Fraction of NO_x emissions required to be removed for scenario compliance.
NOXRMC	Fraction	NO_x removal.
NOXRMN	Fraction	New NO_x removal.
NOXRMO	Fraction	Old NO_x removal.

Table C6-3 (contd.)

Variable	*Units*	*Description*
NOXSDI	Lbs/MMBtu	Initial NO_x standard.
NOXSDN	Lbs/MMBtu	New NO_x standard.
NOXSTD	Lbs/MMBtu	NO_x standard.
NOXTPY	Tons/year	NO_x plant emissions.
NOYRS	-	Index used in obtaining alternative coal data.
NRD		Number of redundant scrubber trains.
NSUL		Number of coal sulfur categories.
NSULCT	-	Number of sulfur categories in a coal classification.
NUNITS		Number of units in unit inventory (data group 70).
NVAL80		Number of values passed to report generator.
NVALS		Number of values passed to report generator.
OILDAT		Array used for writing oil characteristics to unit inventory.
OILHHV	Btu/gallon	Oil heating value.
OILPRC	Cents/MMBtu	Delivered price of oil.
OILSUL	Fraction	Sulfur content.
OILYR	Trillion Btu/yr	Annual oil use.
OLMAX	Grains/SCF	Fabric filter maximum TSP outlet loading.
OMCOST	$/MWh	Operation and maintenance cost at a plant (excluding pollution control).
PCTSUL	Percent	Sulfur content of a coal.
PENLTY	MW	Capacity penalty for TSP control.
PLTCON	Years	Construction time for new coal plants.
PLTEXP	Fraction	Construction schedule for new coal plants.

Table C6-3 (contd.)

Variable	*Units*	*Description*
PRCNOW	Cents/MMBtu	Current price of a coal.
PRICE	Cents/MMBtu	Alternative coal prices from DG 71.
PRJTIM	Years	Period over which pollution control is costed.
PRRTRL	Cents/MMBtu	Cost of a coal in the year a plant is retired.
PRVAL	Cents/MMBtu	Present value of buying a coal over a plant's life.
PRWRTH	$	Present worth of capital charges.
PVDEPN	$	Present value of depreciation schedule for new plants.
PVDEPR	$	Present value of depreciation schedule for retrofit pollution control equipment.
RC	$/ton	FGD reagent cost.
RCDRY	$/ton	Dry FGD reagent cost.
RCLIMB	$/ton	LIMB reagent cost.
RCWET	$/ton	Wet FGD reagent cost.
REGCAT	Codelist L	Regulation category code.
REGN1	Codelist J	Supply region of first coal.
REGN2	Codelist J	Supply region of second coal.
REHEAT	MW	FGD capacity penalty, reheat component.
REMTSP	Fraction	TSP removal.
RETIRE	Year	Plant's retirement year.
RLDSCT	Fraction	Real discount rate.
RSD		Coefficients for the calculation of the coal sulfur relative standard deviation. RSD(I.J) I = 1 - averaging time 21 hours I = 2 - averaging time 30 days I = 3 - averaging time 1 year

Table C6-3 (contd.)

Variable	*Units*	*Description*
		J = 1 - all coals other than cleaned bituminous J = 2 - cleaned bituminous coals
RTRFCT		Retrofit factor for all types of device.
RTRFIT		Code for plant status 0 = new, 1 = existing.
RTRLYR	Year	Retirement year of a plant.
S2OUTO	Fraction	Efficiency of an existing scrubber.
S2PBtu	Lbs/MMBtu	SO_2 emissions from a given coal.
SC	Lbs/MMBtu	Average SO_2 contents in sulfur categories.
SCA	Sq ft/ACFM	Specific collection area of an electrostatic precipitator.
SCBNEW	MW	Scrubber capacity on new plants.
SCBOLD	MW	Scrubber capacity on retrofit plants.
SCHDYR		Index for year in construction schedule.
SLTYP1	-	Sulfur category of first coal in a blend.
SLTYP2	-	Sulfur category of second coal in a blend.
SLWSTI	Ton/hr	Incremental solid waste removal rate.
SLWSTN	Ton/hr	New solid waste removal rate.
SLWSTO	Ton/hr	Old solid waste removal rate.
SO2CAT	Lbs/MMBtu	Boundaries of coal sulfur categories.
SO2COM		Logical variable indication SO_2 compliance.
SO2CYR	Tons/year	Annual emissions of SO_2 from coal plants.
SO2DV	Codelist E	SO_2 control device.
SO2DVC	Codelist E	SO_2 control device.
SO2DVO	Codelist E	Old SO_2 control device.
SO2EML	Lbs/MMBtu	Lower SO_2 emission cap in the RNSPS standards.

Table C6-3 (contd.)

Variable	*Units*	*Description*
SO2EMU	Lbs/MMBtu	Upper SO_2 emission cap in the RNSPS standards.
SO2GEL	Lbs/MMBtu	Lower RNSPS cap for gas plants.
SO2GEU	Lbs/MMBtu	Upper RNSPS cap for gas plants.
SO2GRM	Fraction	Required RNSPS SO_2 removal for gas plants.
SO2GYR	Tons/year	SO_2 emissions from gas plants.
SO2LIM	Fraction	Minimum FGD size constraint used in CALBYP routine.
SO2MWH	Lbs/MWh	SO_2 emission rate.
SO2OEL	Lbs/MMBtu	Lower RNSPS cap for oil plants.
SO2OEU	Lbs/MMBtu	Upper RNSPS cap for oil plants.
SO2ORM	Fraction	Required RNSPS SO_2 removal for oil plants.
SO2OUT	Fraction	Scrubber efficiency (as opposed to sulfur removal).
SO2OYR	Tons/year	SO_2 emissions from oil plants.
SO2PMB	Lbs/MMBtu	SO_2 emission rate.
SO2REM	Fraction	SO_2 removal efficiency.
SO2REQ	Fraction	Fraction of SO_2 removal required for scenario compliance.
SO2RMC	Fraction	SO_2 removal temporary storage.
SO2RML	Fraction	Lower SO_2 removal requirement in the RNSPS standards.
SO2RMN	Fraction	New SO_2 removal.
SO2RMO	Fraction	Old SO_2 removal.
SO2RMU	Fraction	Upper SO_2 removal requirement in the RNSPS.
SO2RMX	Fraction	SO_2 removal temporary storage.
SO2SDI	Lbs/MMBtu	Initial SO_2 standard.
SO2SDN	Lbs/MMBtu	New SO_2 standard.

Table C6-3 (contd.)

Variable	*Units*	*Description*
SO2STD	Lbs/MMBtu	SO_2 standard.
SO2TPY	Tons/year	SO_2 plant emissions.
SOLFRC	Fraction	Solid waste fraction in scrubber sludge.
SOLWST	Tons/hour	Solid waste removal rate.
STDTEM	Degrees Rankine	Standard temperature (528^oR).
SULADJ	Fraction	Sulfur content of coal adjusted for ash retention.
SULFN	Fraction	Sulfur content of new coal.
SULFO	Fraction	Sulfur content of old coal.
SULFUR	Fraction	Sulfur content of a coal.
SUL1	Fraction	Sulfur fraction of first coal in a blend.
SUL2	Fraction	Sulfur fraction of second coal in a blend.
SUM	1000 tons/year or 1000 MMBtu/year	Coal shipments in current year.
TASHYR	Tons/year	Ash production.
TAXRAT	Fraction	Composite federal/state tax rate.
TCC	$	Capital cost of a pollution control device.
TCCFGD	$	Capital cost of a scrubber.
TCCNOX	$	Capital cost of NO_x control.
TCCTSP	$	Capital cost of a TSP control device.
TCCWST	$	Capital cost of waste disposal.
TCHCDE	Codelist B	Plant technology code.
TCHEPS	-	Technology control switch from EPOS data.
TCHSW	-	Technology control switch: 0 = free choice 1 = forced scrubbing

Table C6-3 (contd.)

Variable	*Units*	*Description*
		2 = forced coal switch
TCHTMP	-	Temporary storage for TCHSW.
TDCWD	$	Direct capital cost of waste disposal.
TEMP		Temporary variable.
TFGDSG	Tons/year	Total FGD sludge created.
TOTASH	Tons/year	Total ash creation.
TOTCOS	$/year	Total annual levelized cost of using a coal, including pollution control.
TREMN	Fraction	New TSP removal.
TSO2DV		Temporary variable for storing SO_2 control device
TSPCON	Years	Construction time for TSP control device.
TSPCPN	Lbs/MMBtu	TSP cap for new units.
TSPCYR	Tons/year	TSP emitted from coal plants.
TSPDV	Codelist D	TSP control device code.
TSPDVC	Codelist D	TSP control device passed from SWITCH.
TSPDVN	Codelist D	TSP control device when no SO_2 compliance.
TSPDVO	Codelist D	Old TSP control device.
TSPEXP	Fraction	Construction schedule for TSP devices.
TSPGYR	Tons/year	TSP emitted from gas plants.
TSPIL	Grains/SCF	Fabric filter input loading.
TSPLVC	$/year	Temporary storage for annualized cost of TSP control.
TSPMWH	Lbs/MMBtu	TSP emission rate.
TSPNRD	Fraction	TSP removal required so there is no increase in emissions.
TSPOL	Grains/SCF	Fabric filter output loading.

Table C6-3 (contd.)

Variable	*Units*	*Description*
TSPOYR	Tons/year	TSP emitted from oil plants.
TSPPEN	MW	Capacity penalty for TSP control.
TSPPMB	Lbs/MMBtu	TSP emission rate.
TSPREM	Fraction	TSP removal efficiency.
TSPRMC	Fraction	TSP removal passed from SWITCH.
TSPRMN	Fraction	New TSP removal.
TSPRMO	Fraction	Old TSP removal.
TSPRMT	Fraction	Temporary TSP removal storage.
TSPSDI	Lbs/MMBtu	Initial TSP standard.
TSPSDN	Lbs/MMBtu	New TSP standard.
TSPSTD	Lbs/MMBtu	TSP standard.
TSPTPY	Tons/year	TSP plant emission.
TVC	$/year	Annual variable costs of pollution control.
TVCFGD	$/year	Scrubbing variable costs.
TVCNOX	$/year	Variable cost of NO_x control.
TVCPC	$/year	Variable costs of pollution control.
TVCPCC	Fraction	Temporary storage for total variable cost of pollution control.
TVCTSP	$/year	Variable costs of TSP control.
TVCWST	$/year	Annual variable cost of waste disposal.
TXSCHD	-	Tax depreciation schedule.
TYPE	-	Index for tax depreciation schedule: 1 = retrofit pollution control 2 = new coal plants
UPGRAD		Logical variable to indicate unit cost method of cold ESP upgrade has been selected.

Table C6-3 (contd.)

Variable	*Units*	*Description*
UNCOST		Logical variable to indicate unit cost method of cold ESP upgrade has been considered.
UNEPOS	-	Unit sequence number in EPOS file.
UNSEQ	-	Unit sequence number.
UNTSCT	$/KW	Unit cost of a pollution control device.
VARCOS	$/year	Annual variable cost.
VCFACT		Used to escalate pollution control variable costs above a 1980 level.
VCLVL		Levelization factor for variable pollution control costs.
VCNOXC	$/year	Temporary storage for variable cost of NO_x control.
VCTSP	$/year	Variable cost of TSP control.
VCTSPC	$/year	Variable cost of TSP control passed from SWITCH.
VCWSTC	$/year	Temporary variable cost of waste disposal storage.
VLIST		Used for data transfer with GET and PUT statements.
VLIST1		Used for data transfer with GET and PUT statements.
VOPLS	$/year	Annual operating cost of a scrubber.
VOR	$/year	Annual operating cost of materials handling for scrubber.
W	Ft/min	Migration velocity of particles in electrostatic precipitator.
WEIGHT	-	Weight given to a coal price in calculating the present worth of coal costs over a plant's life.
WFGDSW		Switch for wet FGD/disposal type.

Table C6-3 (contd.)

Variable	*Units*	*Description*
WSTLVL	$/year	Annual levelized cost of waste disposal.
WTFRAC	Fraction	The weight fraction of a coal in a blend.
WTSTRT		FGD reagent/SO_2 weight stoichiometric ratio.
X		One plus real interest rate.
XTOXD	Fraction	Extent of sludge oxidation.
YEARON	Year	Year a new unit comes on line.
YEARS	-	Years for which alternative coal prices are available.
YRBGUN	Year	Year in which new unit construction began.
YRONE	Year	First year of simulation.
YRSTR1	Year	Year to begin limited compliance strategy 1
YRSTR2	Year	Year to begin limited compliance strategy 2
YRSTR3	Year	Year to begin limited compliance strategy 3
YRTOGO		Number of years until a pollution control device comes on line.

Table C6-4
VARIABLE INFORMATION

Variable	Type	Dimension	Units	Data Group	Accessed by
ACCCST	Real	1			CAPCFC, CNSCHD, RREC
ACTTEM	Real	1	Degrees Rankine	30	*, FABACR, FGACFM
ADJUST	Real	1			FGACFM
ADVLRM	Real	1	Fraction		CAPCFC
ALTFUL	Real	7	Cents/MMBtu	74	COMPLY
ASH	Real	1	Fraction	70	COMPLY, IMPACT, FGACFM
ASH1	Real	1		70	IMPACT
ASH2	Real	1		70	IMPACT
ASHN	Real	1	Fraction		TSPBLD, TSPCST
ASHO	Real	1	Fraction		TSPBLD, TSPCST
ASHRET	Real	3	Fraction	30	*, SULASH
AVEOIL	Real	4			COMPLY
AVGTMS	Real	2		Scenario	*, SULVAR
BAGCST	Real	1	$/sq ft	30	*, CCFAB, VCFAB
BAGLIF	Real	1	Years		VCFAB
BAGRC	Real	1	$		VCFAB
BLCOST	Real	1	$/ton		BLEND
BLEND	Logical	1			ALTCOL
BLHHV	Real	1	Btu/lb		BLEND
BOLTYP	Integer	1	Codelist H	70	IMPACT, VCNOX, NOXBLD, COMPLY, PCTLGO, EMITRT, CCNOX, ALTER, NOXIDX, FLYIDX, CNTROL, FREMN
BOTTYP	Integer	1	Codelist G	70	IMPACT, COMPLY, ALTER, FLYIDX, CNTROL, FREMN, NOXIDX, PCTLGO
BOUND1	Real	1	Lbs /MMBtu		FGDBLD, ALTER

Table C6-4 (contd.)

Variable	Type	Dimension	Units	Data Group	Accessed by
BOUND2	Real	1	Lbs /MMBtu		FGDBLD, ALTER
BOUND3	Real	1	Lbs /MMBtu		FGDBLD, ALTER
BTUFR1	Real	1			BLEND
BTUFRC	Real	1	Fraction	70	COMPLY
BTU1	Real	1	Fraction	70	IMPACT
BTU2	Real	1	Fraction	70	IMPACT
BTUYR	Real	1	Btu		IMPACT
BTUYR1	Real	1	Btu		IMPACT
BTUYR2	Real	1	Btu		IMPACT
BYPASS	Real	1	Fraction	70	COMPLY, IMPACT, ALTER, DISPSL PCTLGO, FGDBLD,CALBYP, CCFGDN, CCFGDU,FGDCAP, CCFGDD, CCFGDW, CNTROL, FGDCPD, FGDCPW, FGDCST, VCFGDD, VCFGDW, VCFGD
BYPSSC	Real	1	Fraction		FGDBLD, ALTER, CNTROL
BYPSSO	Real	1	Fraction		FGDBLD, ALTER, CNTROL, FGDCST
CAPAVG	Real	1	Tons/hr		IMPACT, PCTLGO,FGDBLD, VCFGD, VCLIMB, FGDCST, LMBCAP, VCFGDD, VCFGDW
CAPCOS	Real	1	$		PCTLGO, TSPBLD, TSPCST
CAPFAC	Real	1	Fraction		ALTER, PCTLGO, SWITCH, FGDBLD, TSPBLD,TSPCST, DISPSL, CNTROL, FGDCST, IMPACT, NOXBLD, RREC
CAPFGD	Real	1	MW		FGDCST, PCTLGO
CAPPEN	Real	1	MW		COMPLY, IMPACT, ALTER, PCTLGO, SWITCH,FGDBLD, TSPBLD, TSPCST, RREC, CNTROL
CAPPNC	Real	1	MW		ALTER, CNTROL

Reproduced from best available copy.

Table C6-4 (contd.)

Variable	Type	Dimension	Units	Data Group	Accessed by
CAPRSD	Real	1	Tons/hr		FGDBLD, FGDCST, CCFGDN, CCFGDD, CCLIMB, CCFGDW
CCESC	Real	1	Fraction	•	
CCFACT	Real	1			•, CCESPC, CCESPH, CCFAB, RREC, CCNOX
CCFGDC	Real	1	$		FGDBLD, ALTER, CNTROL
CCNOXC	Real	1	$		ALTER, CNTROL
CCTSP	Real	1	$		SWITCH, TSPBLD
CCTSPC	Real	1	$		ALTER, SWITCH, FGDBLD, CNTROL
CCUPGR	Real	1	$/KW		CCFGDU
CCWSTC	Real	1	$		SWITCH, FGDBLD, CNTROL
CF	Real	3	Fraction	30	•, IMPACT, FSEMIT,FTEMIT, VCESP, VCFAB, VCFGD, VCWAST, RREC, VCNOX, CPCTY, VCLIMB, VCFGDD, VCFGDW
CLTYP1	Integer	1			ALTCOL
CLTYP2	Integer	1			ALTCOL
CNDXCP	Real	1			CCESPC, CCESPH, CCFAB, CCFGDN, CCFGDU,CCWAST, VCFAB, VCWAST, VCNOX, CCWAST, CCNOX, CCLIMB, CCFGDD, CCFGDW
CNDXVP	Real	1			VCESP, VCFGD, VCWAST, VCLIMB, VCFGDW, VCFGDD
COAL	Integer	1			SWITCH, FGDBLD, ALTER, CNTROL
COALM	Real	1	Tons/day		IMPACT, ALTER, PCTLGO, SWITCH, FGDBLD,FABACR, FMASH, FMSUL, FSEMIT, FTEMIT, FGDCST, TSPBLD, CNTROL
COALMN	Real	1	Tons/day		TSPBLD, TSPCST

Table C6-4 (contd.)

Variable	Type	Dimension	Units	Data Group	Accessed by
COALMO	Real	1	Tons/day		SWITCH, TSPBLD, TSPCST CNTROL, ALTER
COALS	Real	43,11	Various	72	+
COALVC	Real	1	$/year		SWITCH, FGDBLD, ALTER
COALYR	Real	1	Trillion Btu/year		IMPACT
COLADJ	Real	1	Fraction		FGDCST
COLASH	Real	1	Fraction		COMPLY, PCTLGO,FABACR, FMASH, FREMA, FTEMIT
COLBTU	Real	1	Btu/lb		COLRAT, FREMA, FREMS, SULVAR
COLCLE	Integer	1			SULVAR
COLDAT	Real	22	Various	70	COMPLY
COLHHV	Real	1	Btu/lb		COMPLY, PCTLGO, SULASH FREMN, COLRAT
COLRSD	Real	1	Fraction		IMPACT, FGDCST
COLSUL	Real	1	Fraction		COMPLY, PCTLGO, FMSUL, FSCA, FSEMIT, SULASH, SULVAR
COLTYP	Integer	1			COMPLY, IMPACT, ALTER, FREMN, FGACFM, CNTROL, FLYIDX, NOXIDX PCTLGO, SULASH, SULVAR
CONTIM	Real	1	Years		RREC
COST	Real	1	$		PVCC, CNSCHD
CPNOXC	Real	1	MW		CNTROL
CPRSDN	Real	1	Tons/hr		FGDCST
CPRSDO	Real	1	Tons/hr		FGDCST
CPTSPC	Real	1	MW		SWTCH, FGDBLD, CNTROL
CURBBL	Real	1		OILSWH	

Table C6-4 (contd.)

Variable	Type	Dimension	Units	Data Group	Accessed by
CURCOS	Real	1			ALTER
CUREMM	Real	1			OILSWH
CURHHV	Real	1			OILSWH
CURPRC	Real	1			OILSWH
CURSUL	Real	1			OILSWH
CWIP	Real	1			BLEND
DCCMAT	Real	1	$		CCFGDN, CCFGDD, VCLIMB, CCLIMB, CCFGDW
DCCSCR	Real	1	$		CCFGDN, CCFGDD, CCFGDW
DEFSO2	Real	1	Fraction		*, CALBYP
DEPLTN	Real	41,36,2			IMPACT
DEPREC	Real	1	$		CAPCFC
DESSUL	Real	1	Fraction		FREMS
DEVCON	Integer	1	Years		PVCC, RREC, CNSCHD
DEVEXP	Real	15	Fraction	30	*
DEVTYP	Integer	1			RREC
DFSO2D	Real	1	Fraction	30	*
DFSO2W	Real	1	Fraction	30	*
DISCNT	Real	1	Fraction	Scenario	*, CAPCFC, LVLFAC, LVLCST, PVCC, CNSCHD, PV, PWDEPR
DLNCST	Real	1	$/acre	Scenario	*, CCWAST
DNMNTR	Real	1			FRAC
DRYFGD	Real	5		30	*
DRYSW	Integer	1			COMPLY, ALTER, CNTROL
DRYTEM	Real	1	Degrees Rankine	30	*
DRYYR	Real	1	Year	Scenario	*

Table C6-4 (contd.)

Variable	Type	Dimension	Units	Data Group	Accessed by
DUM1	Real	1			OILSWH
DUM2	Real	1			OILSwh
EFCOAL	Real	10	Ton emission/ ton coal	30	*, FREMN
EFGAS	Real	4	ton emission/ MSCF gas	30	*
EFOIL	Real	5	Lb emission/ th gal oil	30	*
ELCLVL	Real	1			RREC
ELECT	Real	1	MW		FGDCAP, FGDCPD, FGDCPW
ELECYR	Real	1	$/year		RREC
ELRVNU	Real	1	$/MWh		*
EMRATE	Real	1	Lbs/MMBtu		IMPACT
ENERGY	Real	1	GWh	70	IMPACT
EPOSSW	Real	1		Scenario	COMPLY
ESC	Real	1	Fraction		ALTCOL
ESC1	Real	1	Fraction		LVLCST
ESC2	Real	1	Fraction		LVLCST
ESCAL	Real	1			LVLFAC, PVCC, CNSCHD
ESPEFF	Real	1	Fraction		FSCA, FSCAH
ESPUGC	Real	1	$/KW	30	ISPCST
ESPUGV	Real	1		30	TSPCST
EXAIR	Real	5	Fraction	30	*, FGACFM
EXMLTS	Real	2	Fraction	Scenario	*, SULVAR
EXPSCH	Real	1	Fraction		CNSCHD, RREC
FABAC	Real	1	ACFM/sq ft		IMPACT,TSPCST,FABACR,

Table C6-4 (contd.)

Variable	Type	Dimension	Units	Data Group	Accessed by
					CCFAB, VCFAB
FABACO	Real	1	ACFM/sq ft		TSPCST
FABAR	Real	1	Sq ft		CCFAB, VCFAB
FACTOR	Real	1			PVCC, DISPSL, FGDCST, TSPCST
FCTR1	Real	1			CNSCHD
FCTR2	Real	1			CNSCHD
FGDCON	Real	1	Years	30	*
FGDEXP	Real	5	Fraction	30	*
FGDG	Real	1	ACFM		CCFGDN, VCFGD, VCFGDW, FGDCPD, FGDCPW, CCFGDD, CCFGDW
FGDGEN	Real	1	MW		CALBYP, CCFGDN, CCFGDD, CCFGDW, VCFGDD
FGDPEN	Real	1	MW		IMPACT
FGDMIN	Real	1	MW	30	*, CALBYP
FGDSLG	Real	1	Tons/year		IMPACT
FLYASH	Real	7	Fraction	30	*, FABACR, FMASH, FREMA, FTEMIT
FRAC1	Real	1	Fraction		BLEND
FRAC2	Real	1	Fraction		BLEND
FTYPE	Real	1		70	IMPACT
FUELYR	Real	1	Trillion Btu/yr	70	IMPACT
FXCHFC	Real	1	Fraction		RREC
G	Real	1	ACFM		IMPACT,PCTLGO,SWITCH, FGDBLD,TSPBLD,TSPCST, FABACR,CCFGDN,ESPCPC, ESPCPH,FGDCAP,VCESP, VCFAB,VCFGD, ALTER, CCESPC,

Table C6-4 (contd.)

Variable	Type	Dimension	Units	Data Group	Accessed by
					CCESPH, CCFAB, CCFGDD, CCFGDW, CNTROL, FGDCPD, FGDCPW, FGDCST, VCFGDW
GASYR	Real	1	Trillion Btu/yr		IMPACT
GEN	Real	1	MW	70	COMPLY,IMPACT, ALTER, PCTLGO,SWITCH,FGDBLD, TSPBLD,TSPCST,DISPSL, CALBYP,COLRAT,FGACFM, CCESPC,CCESPH, CCFAB, CCFGDN,CCFGDU, VCFAB, VCWAST, VCNOX, NOXCAP, NOXBLD, CCFGDD, CCFGDW, CCLIMB, CCNOX, CCWAST
GHOT	Real	1	ACFM		TSPCST
GRSGEN	Real	1	MW	70	COMPLY, FGDCST, VCFGDD, IMPACT, ALTER, CNTROL
HEATRT	Real	1	Btu/KWh	70,23	COMPLY,IMPACT,ALTER, PCTLGO,SWITCH,FGDBLD, COLRAT,FGACM,FGDCAP OILSWH, LMBCAP, FGDCPW, FGDCST, CNTROL, EMITRT, FGDCPD
HHV	Real	1	Btu/lb	70	COMPLY, IMPACT, EMITRT, FGACM
HHV1	Real	1	Btu/lb	70	COMPLY, BLEND, FRAC, IMPACT
HHV2	Real	1	Btu/lb	70	COMPLY, BLEND, FRAC, IMPACT
ICCOST	Real	1			CCFGDN, CCFGDU, CCWAST, CCLIMB, CCFGDD, CCFGDW
ICF	Real	10		30	CCESPC, CCESPH, CCFAB, CCFGDN, CCFGDU, CCWAST CCFGDD, CCFGDW, CCLIMB, CCNOX
ICFLF	Real	1			CCWAST
ICFPND	Real	1			CCWAST
ICLEN	Integer	1			SULVAR

Table C6-4 (contd.)

Variable	Type	Dimension	Units	Data Group	Accessed by
ICMPLY	Integer	1	Year	32	COMPLY
ICOLCT	Integer				+
ICOLSZ	Integer	1			+
IDUMMY	Integer	1			LVLCST
IDX	Integer	1			COMPLY, BLEND, FREMN, FSCAH, FSCA, PCTLGO
IDX1	Real	1			LVLCST
IDX2	Real	1			LVLCST
IDXCL1	Integer	1			ALTCOL
IDXCL2	Integer	1			ALTCOL
IDXCOL	Integer	1			ALTCOL, LVLCST
IDXFLY	Integer	1			IMPACT, CNTROL, PCTLGO, TSPBLD, TSPCST
IDXGET	Integer	1			ALTCOL
IDXNOW	Integer	1			ALTCOL
IDXNOX	Integer	1			COMPLY
IDXNXT	Integer	1			ALTCOL
IDXOFF	Integer	1			ALTCOL, LVLCST
IDXON	Integer	1			ALTCOL, LVLCST
IDXSO2	Integer	1			COMPLY, ALTCOL
IDXTSP	Integer	1			COMPLY
IFCODE	Integer	1	Codelist C	70	COMPLY, EMITRT
IGT20	Integer	14			COMPLY
IGT60	Integer	4			COMPLY
IGT61	Integer	4			COMPLY

Table C6-4 (contd.)

Variable	Type	Dimension	Units	Data Group	Accessed by
IGTAVR	Integer	3			COMPLY
IGTCOL	Integer	22			COMPLY
IGTNEW	Integer	6			COMPLY
IGTOIL	Integer	4			COMPLY
IGTRTR	Integer	16			COMPLY
IGTTX	Integer	15			COMPLY
IGTXST	Integer	18			COMPLY
INFLAT	Real	1	Fraction	Scenario	*, CAPCFC, LVLFAC, PVCC, CNSCHD
INOXCP	Integer	1		70	COMPLY, ALTER, CNTROL
INTCST	Real	1	Cents/MMBtu		ALTCOL, LVLCST
IPT32	Integer	9			COMPLY
IPTALT	Integer	8			COMPLY
IPTCON	Integer	8			COMPLY
IPTINT	Integer	6			COMPLY
IPTNEW	Integer	16			COMPLY
IPTOIL	Integer	5			COMPLY
IPTRTR	Integer	15			COMPLY
IPTXST	Integer	6			COMPLY
IRID	Integer	1			IMPACT
IRID80	Integer	1			IMPACT
IRTRO	Integer	1			COMPLY
ISO2CP	Integer	1	Year	70	COMPLY, ALTER
ISTATE	Integer	1	Codelist 1		COMPLY,IMPACT,ALTCOL
ISTOP	Integer	1			IMPACT

Table C6-4 (contd.)

Variable	Type	Dimension	Units	Data Group	Accessed by
ISUB	Integer	1			IMPACT, COMPLY
ISUB80	Integer	1			IMPACT
ISUPPL	Integer	1			IMPACT
IT1	Integer	1			COMPLY
ITC	Integer	1	$		CAPCFC, CNSCHD, RREC
ITCELG	Real	2	Fraction	60	*, CNSCHD
ITCHCD	Integer	1	Codelist F	23	COMPLY
ITCHFC	Integer	23			COMPLY
ITCRAT	Real	1	Fraction	60	*, CNSCHD
ITMP	Integer	1			IMPACT
ITMS	Integer	1			SULVAR
ITRACE	Integer	1			COMPLY, IMPACT, OILSWH
ITSPCP	Integer	1		70	COMPLY,ALTER,SWITCH, FGDBLD, CNTROL
IUNSEQ	Integer	1			COMPLY,IMPACT
IVCOST	Real	1			VCESP,VCFAB,VCFGD, VCWAST, VCLIMB, VCFGDD, VCFGDW
IYEAR	Integer	1	Year		COMPLY,IMPACT,ALTCOL ALTER,SWITCH,FGDBLD, CPCTY, CNTROL
JCAT	Integer	1			IMPACT
JH1	Integer	1			IMPACT
JH2	Integer	1			IMPACT
KS	Integer	1			IMPACT
LAND	Real	1	$/acre		CCWAST
LEAD	Real	1	Years		*, CPCTY,LVLFAC,PVCC, CNSCHD

Table C6-4 (contd.)

Variable	Type	Dimension	Units	Data Group	Accessed by
LIFCST	Real	1	Cents/MMBtu		ALTCOL, LVLCST
LIFE	Real	1	Years	20	*, CAPCFC, LVLCST, PCTLGO
LIMB	Real	10			*
LIMBYR	Real	1	Year	Scenario	*
LIMBSW	Integer	1		Scenario	COMPLY, ALTER, CNTROL
LMSTR1	Real	1		Scenario	*
LMSTR2	Real	1		Scenario	*
LMSTR3	Real	1		Scenario	*
LNR	Real	1	Log (ohm-cm)		FSCA
LVLCOS	Real	1	$/year		PCTLGO,TSPBLD, ALTER, CNTROL
LVLCSC	Real	1	$/year	CNTROL	
LVLNOX	Real	1	$/year	IMPACT,NOXBLD	
LVLTSP	Real	1	$/year		TSPBLD
MAREM	Real	1	Tons/hr		IMPACT,PCTLGO,CCWAST VCWAST
MAREMI	Real	1	Tons/hr		DISPSL
MAREMN	Real	1	Tons/hr		ALTER,SWITCH,FGDBLD, DISPSL, CNTROL
MAREMO	Real	1	Tons/hr		ALTER,SWITCH,FGDBLD, DISPSL, CNTROL
MAX	Integer	1			FGDBLD, ALTER
MIN	Integer	1			FGDBLD, ALTER
MODCST	Real	1	$		CCFGDN, CCFGDD, CCFGDW, CCLIMB
MSR	Real	1			WSR
MSREM	Real	1	Tons/hr		IMPACT,PCTLGO,SLUDGE, CCFGDN,CCWAST,FGDCAP,

Table C6-4 (contd.)

Variable	Type	Dimension	Units	Data Group	Accessed by
					VCFGD,VCWAST, FGDCPW, FGDCST, CCFGDW, VCFGDW
MSREMI	Real	1	Tons/hr		DISPSL
MSREMN	Real	1	Tons/hr		ALTER,SWITCH,FGDBLD, DISPSL, CNTROL
MSREMO	Real	1	Tons/hr		ALTER,SWITCH,FGDBLD, DISPSL, CNTROL, FGDCST
MSREMP	Real	1	Tons/hr		FGDBLD, FGDCST
MSRLIMB	Real	1	Tons/hr		WSR
MST	Real	3	Fraction		FGACFM
MULT	Real	1		70	IMPACT
NCOALS	Real	1			IMPACT
NETGEN	Real	1	MW	70	IMPACT
NEWBBL	Real	1	$		OILSWH
NEWCOL	Integer	1			COMPLY,ALTER,SWITCH, FGDBLD
NEWOIL	Logical	1			COMPLY, OILSWH
NEWUN	Integer	1			COMPLY
NHHV	Integer	1			IMPACT
NHHVCT	Integer	2			COMPLY, IMPACT, ALTCOL
NMRTR	Real	1			FRAC
NOCOLS	Integer	1			+
NOHHV	Integer	1			COMPLY, ALTCOL
NONEW	Integer	1			COMPLY
NOP	Real	1			CCFGDN
NORTRO	Integer	1			COMPLY

Table C6-4 (contd.)

Variable	Type	Dimension	Units	Data Group	Accessed by
NOSUL	Integer	1			ALTCOL
NOXCOM	Logical	1			COMPLY, ALTER
NOXCON	Real	1	Years	30	*
NOXCPC	Real	1	Lbs/MMBtu	31	*
NOXCPG	Real	1	Lbs/MMBtu	31	*
NOXCPO	Real	1	Lbs/MMBtu	31	*
NOXCPS	Real	1	Lbs/MMBtu	31	*
NOXCYR	Real	1	Tons/yr		IMPACT
NOXDV	Integer	1		70	COMPLY, IMPACT, ALTER, VCNOX, NOXCAP, CNTROL, CCNOX, PCTLGO
NOXDVC	Integer	1			ALTER,CNTROL
NOXDVN	Integer	1			NOXBLD
NOXDVO	Integer	1			ALTER, CNTROL, NOXBLD
NOXEXP	Real	5	Fraction	30	*
NOXGYR	Real	1	Tons/yr		IMPACT
NOXLIM	Real	1	Lbs/MMBtu		PCTLGO
NOXLVL	Real	1	$/year		CNTROL
NOXMWH	Real	1	Lbs/MWh	70	COMPLY, IMPACT, EMITRT, PCTLGO
NOXOYR	Real	1	Tons/yr		IMPACT
NOXPEN	Real	1	MW		IMPACT
NOXPMB	Real	1	Lbs/MMBtu		EMITRT, FREMN, PCTLGO
NOXREM	Real	1	Fraction	33,70	COMPLY, IMPACT, ALTER, PCTLGO, CNTROL
NOXREQ	Real	1	Fraction		COMPLY, ALTER, CNTROL

Table C6-4 (contd.)

Variable	Type	Dimension	Units	Data Group	Accessed by
NOXRMC	Real	1	Fraction		ALTER, CNTROL
NOXRMN	Real	1	Fraction		NOXBLD
NOXRMO	Real	1	Fraction		ALTER, CNTROL, NOXBLD
NOXSDI	Real	1	Lbs/MMBtu	70	IMPACT, COMPLY
NOXSDN	Real	1	Lbs/MMBtu	70	COMPLY
NOXSTD	Real	1		70	COMPLY, ALTER, CNTROL, FREMN
NOXTPY	Real	1	Tons/yr		IMPACT
NOYRS	Integer	1			ALTCOL
NRD	Real	1			CCFGDN, CCFGDD, CCFGDW
NSUL	Integer	1			IMPACT
NSULCT	Integer	2			IMPACT, ALTCOL
NUNITS	Integer	1			COMPLY,IMPACT
NVAL80	Integer	1			IMPACT
NVALS	Integer	1			IMPACT, COMPLY
OILDAT	Real	5			COMPLY
OILHHV	Real	1	Btu/gallon	70	COMPLY, OILSWH
OILPRC	Real	1	Cents/MMBtu	70	COMPLY, OILSWH
OILSUL	Real	1	Fraction	70	COMPLY, OILSWH
OILYR	Real	1	Trillion Btu/yr		IMPACT
OLMAX	Real	1	Grains/SCF	30	*, FABACR
OMCOST	Real	1	$/MWh	70	COMPLY, ALTER, IMPACT
PCTSUL	Real	1	Percent		FSCA
PENLTY	Real	1	MW		TSPBLD, NOXBLD
PLTCON	Real	1	Codelist A	20	*

Table C6-4 (contd.)

Variable	Type	Dimension	Units	Data Group	Accessed by
PLTEXP	Real	12	Codelist A	20	*
PRCNOW	Real	1	Cents/MMBtu		ALTCOL
PRICE	Real	11	Cents/MMBtu	70	IMPACT, ALTCOL, LVLCST
PRJTIM	Real	1	Years		ALTER,SWITCH,FGDBLD, TSPBLD,DISPSL,LVLFAC, RREC, NOXBLD, CAPCFC, CNTROL
PRRTRL	Real	1	Cents/MMBtu		LVLCST
PRVAL	Real	1	Cents/MMBtu		LVLCST
PRWRTH	Real	1	$	CAPCFC	
PVDEPN	Real	1	$	*, CAPCFC	
PVDEPR	Real	1	$	*, CAPCFC	
RC	Real	1	$/ton		VCFGDD, VCFGDW, VCLIMB
RCDRY	Real	1	$/ton	Scenario	*
RCLIMB	Real	1	$/ton	Scenario	*
RCWET	Real	1	$/ton	Scenario	*
REGCAT	Integer	1	Codelist L	70	COMPLY
REGN1	Real	1		70	IMPACT
REGN2	Real	1		70	IMPACT
REHEAT	Real	1	MW		FGDCAP, FGDCPD, FGDCPW
REMTSP	Real	1	Fraction		FMASH
RETIRE	Integer	1	Year	70	COMPLY,ALTCOL,ALTER, IMPACT, LVLCST, PCTLGO
RLDSCT	Real	1			ALTCOL, CAPCFC, LVLFAC
RSD	Real	3,2	Fraction	30	*, SULVAR
RTRFCT	Real	1		30	*, TSPCST, CCESOC, CCWAST, CCNOX, CCESPH, CCLIMB,

Table C6-4 (contd.)

Variable	Type	Dimension	Units	Data Group	Accessed by
					CCFAB, CCFGDD, CCFGDW
RTRFIT	Integer	1			ALTER,FGDBLD,TSPBLD, TSPCST,CCESPC,CCESPH, CCFAB, FGDCST, VCNOX, DISPSL, COMPLY, ALTCOL, CAPCFC, CCNOX, CNSCHD, CNTROL, TSPCST, NOXBLD, RREC
RTRLYR	Integer	1	Year		CPCTY
S2OUTO	Real	1	Fraction		FGDCST
S2PBtu	Real	1	Lbs/MMBtu		ALTER
SC	Real	22	Lbs/MMBtu		ALTCOL
SCA	Real	1	Sq ft/ACFM		IMPACT,TSPCST,CCESPC, CCESPH,ESPCPC,ESPCPH, VCESP
SCBNEW	Real	1	MW		COMPLY
SCBOLD	Real	1	MW		COMPLY
SCHDYR	Integer	1			PVCC, CNSCHD
SLTYP1	Integer	1			ALTCOL
SLTYP2	Integer	1			ALTCOL
SLWSTI	Real	1	Tons/hour		DISPSL
SLWSTN	Real	1	Tons/hour		DISPSL
SLWSTO	Real	1	Tons/hour		DISPSL
SO2CAT	Real	22	Lbs/MMBtu		IMPACT, ALTCOL
SO2COM	Logical	1			COMPLY, ALTER
SO2CYR	Real	1	Tons/yr		IMPACT
SO2DV	Integer	1	Codelist E	32,70	COMPLY,IMPACT,ALTER, PCTLGO, CCWAST, CNTROL, WSR, VCWAST, TSPCST, TSPBLD, SLUDGE, NOXBLD,

Table C6-4 (contd.)

Variable	Type	Dimension	Units	Data Group	Accessed by
					FGDCST, DISPSL
SO2DVC	Integer	1			ALTER, CNTROL
SO2DVO	Integer	1	Codelist E		ALTER, COMPLY, CNTROL, DISPSL
SO2EML	Real	1	Lbs/MMBtu	31	•
SO2EMU	Real	1	Lbs/MMBtu	31	•
SO2GEL	Real	1	Lbs/MMBtu	31	•
SO2GEU	Real	1	Lbs/MMBtu	31	•
SO2GRM	Real	1	Fraction	31	•
SO2GYR	Real	1	Tons/yr		IMPACT
SO2LIM	Real	1	Fraction		CALBYP
SO2MWH	Real	1	Lbs/MWh	70	COMPLY, IMPACT, EMITRT, OILSWH, PCTLGO
SO2OEL	Real	1	Lbs/MMBtu	31	•
SO2OEU	Real	1	Lbs/MMBtu	31	•
SO2ORM	Real	1	Fraction	31	•
SO2OUT	Real	1	Fraction		COMPLY,IMPACT,PCTLGO, FGDBLD, CALBYP, FGDCST, DISPSL
SO2OYR	Real	1	Tons/yr		IMPACT
SO2PMB	Real	1	Lbs/MMBtu		IMPACT, EMITRT
SO2REM	Real	1	Fraction	70	COMPLY,ALTER,PCTLGO, FGDBLD,CALBYP,FMSUL, FSEMIT,SLUDGE,CCFGDN, VCFGD, OILSWH, WSR, IMPACT, CNTROL, DISPSL
SO2REQ	Real	1			COMPLY, ALTER
SO2RMC	Real	1			ALTER, CNTROL

Table C6-4 (contd.)

Variable	Type	Dimension	Units	Data Group	Accessed by
SO2RML	Real	1	Fraction	31	*
SO2RMN	Real	1	Fraction		ALTER,SWITCH,FGDBLD FGDCST
SO2RMO	Real	1	Fraction		SWITCH, FGDBLD, FGDCST, ALTER, CNTROL
SO2RMU	Real	1	Fraction	31	*
SO2RMX	Real	1			ALTER, CNTROL
SO2SDI	Real	1	Lbs/MMBtu	70	COMPLY,IMPACT
SO2SDN	Real	1	Lbs/MMBtu	70	COMPLY
SO2STD	Real	1	Lbs/MMBtu	70	COMPLY,ALTER,SWITCH FGDBLD,BLEND,FRAC, FREMS, OILSWH
SO2TPY	Real	1	Tons/yr		IMPACT
SOLFRC	Real	5	Fraction	30	*, SLUDGE
SOLWST	Real	1	Tons/hr		CWAST
STDTEM	Real	1	Degrees Rankine		FABACR
SULADJ	Real	1	Fraction		PCTLGO, IMPACT
SULFN	Real	1	Fraction		TSPBLD,TSPCST
SULFO	Real	1	Fraction		TSPBLD,TSPCST
SULFUR	Real	1	Fraction	70	FGDCAP, FGDCPW, COMPLY, IMPACT, EMITRT
SUL1	Real	1	Fraction	70	FRAC, IMPACT, ALTCOL
SUL2	Real	1	Fraction	70	FRAC, IMPACT, ALTCOL
SUM	Real	1			IMPACT
TASHYR	Real	1	Tons/yr		IMPACT
TAXRAT	Real	1	Fraction		*, CAPCFC
TCC	Real	1	$		PVCC,RREC

Table C6-4 (contd.)

Variable	Type	Dimension	Units	Data Group	Accessed by
TCCFGD	Real	1	$	32	COMPLY, ALTER, FGDBLD, FGDCST, PCTLGO, IMPACT, CNTROL
TCCNOX	Real	1			COMPLY, IMPACT, ALTER, CNTROL, NOXBLD
TCCTSP	Real	1	$	31	COMPLY,IMPACT,ALTER FGDBLD, CNTROL
TCCWST	Real	1	$		IMPACT, DISPSL, PCTLGO
TCHCDE	Real	1		70	IMPACT
TCHSW	Integer	1			COMPLY, ALTER, CNTROL
TCHTMP	Integer	1			COMPLY
TDCWD	Real	1	$		CCWAST
TEMP	Real	1			COMPLY, IMPACT, TSPCST
TFGDSG	Real	1	Tons/yr		IMPACT
TOTASH	Real	1	Tons/yr		IMPACT
TOTCOS	Real	1	$/yr		SWITCH, FGDBLD, ALTER
TREMN	Real	1	Fraction		FABACR
TSO2DV	Real	1			IMPACT
TSPCON	Real	1	Years	30	*
TSPCPN	Real	1	Lbs/MMBtu	31	*
TSPCYR	Real	1	Tons/yr		IMPACT
TSPDV	Integer	1	Codelist D	70	COMPLY, IMPACT, ALTER, PCTLGO, SWITCH, FGDBLD, CNTROL
TSPDVC	Integer	1	Codelist D		ALTER,SWITCH,FGDBLD CNTROL
TSPDVN	Integer	1	Codelist D		ALTER,TSPBLD,TSPCST
TSPDVO	Integer	1	Codelist D		SWITCH, FGDBLD, TSPBLD,

Table C6-4 (contd.)

Variable	Type	Dimension	Units	Data Group	Accessed by
					TSPCST, ALTER, CNTROL
TSPEXP	Real	5	Fraction	30	*
TSPGYR	Real	1	Tons/yr		IMPACT
TSPIL	Real	1	Grains/SCF		FABACR
TSPLVC	Real	1	$/year		SWITCH, FGDBLD, CNTROL
TSPMWH	Real	1	Lbs/MWh	70	COMPLY, IMPACT, EMITRT, PCTLGO
TSPNRD	Real	1	Fraction		CNTROL
TSPOL	Real	1	Grains/SCF		FABACR
TSPOYR	Real	1	Tons/yr		IMPACT
TSPPEN	Real	1	MW		IMPACT
TSPPMB	Real	1	Lbs/MWh		EMITRT
TSPREM	Real	1	Fraction	70	COMPLY, ALTER, PCTLGO, TSPBLD, FTEMIT, IMPACT, CNTROL
TSPRMC	Real	1	Fraction		ALTER, SWITCH, FGDBLD, CNTROL
TSPRMN	Real	1	Fraction		ALTER, SWITCH, FGDBLD, TSPBLD, TSPCST
TSPRMO	Real	1	Fraction		SWITCH, FGDBLD, TSPBLD, TSPCST, ALTER, CNTROL
TSPRMT	Real	1	Fraction		TSPCST
TSPSDI	Real	1	Lbs/MMBtu	70	COMPLY,IMPACT
TSPSDN	Real	1	Lbs/MMBtu	70	COMPLY
TSPSTD	Real	1	Lbs/MMBtu	70	COMPLY,ALTER,SWITCH FGDBLD, FREMA, CNTROL
TSPTPY	Real	1	Tons/yr		IMPACT
TVC	Real	1	$/year		RREC

Table C6-4 (contd.)

Variable	Type	Dimension	Units	Data Group	Accessed By
TVCFGD	Real	1	$/year		IMPACT, FGDCST, PCTLGO
TVCNOX	Real	1	$/year		IMPACT, NOXBLD
TVCPC	Real	1	$/year	32, 70	COMPLY, ALTER, PCTLGO, FGDBLD, IMPACT, CNTROL
TVCPCC	Real	1	Fraction		ALTER, CNTROL
TVCTSP	Real	1	$/year		IMPACT
TVCWST	Real	1	$/year		IMPACT, DISPSL, PCTLGO
TXSCHD	Real	15		60	COMPLY, PCTLGO
TYPE	Integer	1			PCTLGO
UNCOST	Logical	1			TSPBLD, TSPCST
UNSEQ	Real	1		70	IMPACT, VCLIMB
UNTCST	Real	1	$/kW		CCFGDD, CCLIMB
UPGRAD	Logical	1			TSPBLD, TSPCST
VARCOS	Real	1	$/year		TSPBLD, TSPCST
VCFACT	Real	1			• VCNOX
VCLVL	Real	1			RREC
VCNOXC	Real	1	$/year		CNTROL
VCTSP	Real	1	$/year		SWITCH, TSPBLD
VCTSPC	Real	1	$/year		ALTER, SWITCH, FGDBLD, CNTROL
VCWSTC	Real	1	$/year		SWITCH, FGDBLD, CNTROL
VLIST	Real	36			COMPLY, IMPACT, ALTCOL
VLIST1	Real	6			COMPLY
VOPLS	Real	1	$/year		VCFGD, VCFGDD, VCFGDW
VOR	Real	1	$/year		VCFGD, VCFGDD, VCFGDW, VCLIMB

Table C6-4 (contd.)

Variable	Type	Dimension	Units	Data Group	Accessed by
W	Real	1	Ft/min		FSCA,FSCAH
WEIGHT	Real	1			LVLCST
WFGDSW	Real	1		30	*, CCFGDW, CCWAST, SLUDGE, VCWAST, FGDCPW, VCFGDW
WSTLVL	Real	1	$/year		IMPACT, ALTER, SWITCH, CNTROL, DISPSL, PCTLGO FGDBLD
WTFRAC	Real	1	Fraction		COMPLY, ALTCOL, IMPACT, DISPSL, SLUDGE
WTSTRT	Real	1			IMPACT, DISPSL, SLUDGE
X	Real	1			CAPCFC,LVLFAC
XTOXD	Real	5	Fraction		SLUDGE
YEARON	Integer	1	Year	23, 70	COMPLY, IMPACT, ALTCOL, SULVAR, PCTLGO, EMITRT, LVLCST
YEARS	Real	11			ALTCOL, LVLCST
YRBGUN	Integer	1	Year	23	COMPLY
YRONE	Real	1	Year	Scenario	*
YRSTR1	Real	1	Year	Scenario	*
TRSTR2	Real	1	Year	Scenario	*
TRSTR3	Real	1	Year	Scenario	*
YRTOGO	Real	1	Years		COMPLY, PVCC, CNSCHD

* - *Variables are in the /CTNATL/ common block which is passed to the following subroutines: COMPLY, FGDBLD, IMPACT, TSPBLD, ALTCOL, TSPCST, ALTER, DISPSL, PCTLGO, RREC, SWITCH, CNTROL, EMITRT, RREC, NOXBLD, FGDCST.*

+ - *Variables are in the /COLINF/ common block which is passed to the following subroutines: COMPLY, ALTCOL, ALTER, BLEND, SWITCH, FGDBLD, IMPACT, CNTRL.*

Reproduced from best available copy.

APPENDIX C6a. SIMULATING MARKET MANAGEMENT SYSTEMS USING THE ADVANCED UTILITY SIMULATION MODEL

by
James S. Diemer

Universities Research Group on Energy
University of Illinois at Urbana-Champaign

6a.1 Introduction

The pollution control module of the Advanced Utility Simulation Model (AUSM) serves two principal functions. The COMPLY subroutine controls the logic flow for the selection and implementation of pollution control strategies for new units and existing units participating in an emissions control program. The IMPACT subroutine controls the logic flow for determining the annual output of electricity, emissions and solid wastes for individual generating units. AUSM is capable of simulating several pollution control management scenarios. Although simulation of other management strategies is possible, state scenario variables have been incorporated to conveniently execute the simulation of SIP Compliance, SIP Rollback, Emissions Charges and Permit Market management programs for sulfur dioxide pollutants. This appendix to the pollution control module program documentation serves to describe in detail the execution of these management programs in the pollution control module. Simulating these management programs is part of Task 5 of the COMPLY subroutine, which is described in Chapter C6, The Pollution Control Module. This appendix is primarily concerned with Section 3 of the COMPLY subroutine: Scan of the Unit Inventory and associated management program data-handling routines. Chapter C6, of this document, contains a general discussion of the other components of the pollution control module.

6a.2 Logic Flow for Section 3 of COMPLY: Scan of Unit Inventory File

The basic logic flow of Section 3 of COMPLY is very simple and is discussed in detail in Section 6.2.1.4. In each year of the simulation, the unit inventory is scanned to identify units that are required to make a pollution control compliance decision. For each of these units ALTCOL is called to create a list of potential fuel candidates and ALTER is called to determine the potential compliance options for the unit. Supervision of the calculation of the cost of every allowable compliance strategy is carried out by the CNTROL subroutine. A description of the most cost-effective compliance option is sent to the retrofit files by COMPLY. This logic flow is sufficient when pollution control compliance is dictated by an emissions standard. This is the case for the SIP Compliance and SIP Rollback management approaches. For these scenarios, each unit is assigned a standard – in the rollback scenario the new standard is a fraction (generally a function of the percent reduction of the state's emissions) of the SIP standard. For management approaches where unit specific standards are not available, this logic flow must be expanded.

Simulation of a least-cost pollution control strategy in the form of market systems or emissions charges requires that pollution control cost curves be generated for a range of emission reductions for each unit participating in the program. Cost curve generation is carried out by altering the logic outlined above by conducting a parametric analysis on a unit's SIP emissions standard. Thus for each unit participating in the program, the COMPLY subroutine calls ALTER several times (generally three to five times) to determine the least-cost compliance strategy for a series of various levels of pollution abatement.

Once a unit's cost curve is available, the determination of the optimal control strategy for the unit is controlled by either the SORT or FUTURS subroutines. For the emissions charge management approach or the permit market program where the permit prices are available from the MPMS preprocessor, the FUTURS subroutine selects the appropriate level of pollution abatement for a unit. This is accomplished by transforming the cost curve into a marginal cost curve. The point on the cost curve where the marginal cost approximates the permit price (or emissions fee) is passed to COMPLY as the optimal operating point for a unit provided the unit experiences a positive total savings by selecting this compliance strategy. COMPLY places this information in the retrofit files.

In simulating a permit market where permit prices are not known prior to the simulation, the SORT subroutine controls the selection of the pollution control strategies. The selection of control strategies is made based on the system-wide permit demand curve and the allowable emissions level for the market participants in the region (the emissions cap). Thus control strategies cannot be selected until the cost curves of all the market participants are available. As the cost curve is generated for each unit, SORT is called to remove concavities in the curve, calculate the marginal cost of pollution control, and to store a description of the compliance strategy in the OPCHAR array. Upon completion of cost curve generation, subroutine RANK carries out a merit ordering of the compliance options for the system. Options are ranked by increasing marginal cost. Finally, subroutine GRANDF determines the compliance strategy for each unit by selecting the compliance options with the lowest marginal costs until the emissions reduction is sufficient to meet the emissions cap. A description of the compliance action for units that change fuels, add or upgrade devices is placed in the retrofit files by GRANDF.

Implementation of these strategies via the global- and state-level scenario parameters is discussed in the Control Program (Chapter C3). Descriptions of the individual subroutines employed in Emission Charge and Market Programs are presented below.

```
Initialize Global Management Variables for the Year
DO for each unit
    Obtain Unit Data From DG70
    In the first year determine the variable pollution control costs, capacity penalty and pollution
    emissions rate (Call PCTLGO and EMITRT).
    IF a unit is coal fired
        IF it is a pollution control decision year
            Obtain fuel data from unit inventory.
            Determine the number of new standards for which pollution control strategies must
            be determined (1 for standard base compliance or for market programs for NSPS
            coal units with scrubbers; 3-5 for market programs for coal units without scrubbers).
            DO for each possible new standard
                Create a list of alternative coals (Call ALTCOL).
                IF this is the first new standard for a market program, THEN determine
                cost and emissions level of continued operation at the existing standard.
                Find least cost compliance option to meet new standard (Call ALTER).
                IF some compliance is necessary to meet the new standard, THEN
                    IF the management scenario is not a market program, THEN put
                    compliance strategy characteristics to the retrofit file.
                    IF the management scenario is a market program, THEN calculate
                    the emissions rate and marginal cost of this compliance option.
                IF a FUTURS market, THEN compare marginal cost to permit price, and for the last call for each unit send pollution control strategy to the retrofit files (Call FUTURS)

                IF a SORT market, THEN check cost curve for concavities and store the compliance option (Call SORT)

            END IF

        END DO

        IF a SORT market, THEN add the various steps for this unit's cost curve to the system permit demand curve (Call RANK)

    END IF

  END IF

END DO

IF a SORT market, THEN choose pollution control options for each market participant based on the emission cap and the system permit demand curve (Call GRANDF)

IF a FUTURS market, THEN write the cumulative totals of permit trading activities to the TDP report (Call FUTURS)

END
```

6a.3 Subprogram Summaries

The four subroutines used in carrying out the TDP simulations are described in this section.

6a.3.1 Subroutine FUTURS

Called by:	COMPLY	
Calls:	None	
Arguments:	ISTATE	- state FIPS code
	IYEAR	- simulation year
	BASCST	- total annual levelized cost of fuel and pollution control devices for continued operation of a unit for its remaining life
	BASTPY	- tons of SO_2 emitted per year at the present level of pollution abatement (control option corresponding to BASCST)
	CSTMAR	- marginal cost of pollution abatement for the MARTRY segment of an SO_2 abatement cost curve
	IUNSEQ	- unit sequence number

LASTSW - switch equal to 1 (by default equals zero) on call to subroutine FUTURS to write cumulative totals for TDP report 810

MARTRY - number of the attempt made in obtaining a point on the SO_2 abatement cost curve (ranges in value from 1 to NOTRY)

MKTNUM - market identification number assigned to a coal unit participating in the SO_2 permit market

NOTRY - total number of attempts made in generating points of a unit's SO_2 abatement cost curve (equals 1 by default, ranges from 3 to 5 for market simulation participants)

PRVCST - total annual levelized cost of operation (fuel and pollution control) for a discharger's control option with the greatest marginal cost

PRVTYP - annual SO_2 emissions level for the discharger's control option with the greatest marginal cost

SO2TPY - tons of SO_2 emitted per year for the MARTRY control option

TANCOS - total annual levelized cost of choosing the MARTRY operating point

VLIST - 33 operating characteristics of the MARTRY control option

YROFF - retirement year based on capacity factor projections for the purposes of choosing a pollution control option

Tasks: To select the best pollution control strategy for each generating unit participating in a permit market when the permit price is known from the MPMS simulation. If a unit takes some action in the market, construction and fuel characteristics are placed in the retrofit files. The control options and permit trading activity of each unit is written to unit 80.

Method:

```
IF the marginal cost of pollution abatement for the cost curve segment is
    less than or equal to the permit price and the unit has a total savings
    by taking a compliance action, THEN

        Store the cost curve point as the best control strategy available
        (IBEST).
        Place the 33 characteristics that define the cost curve point in the FEATUR array.

    END IF

    IF this is the last attempt at generating a segment of a unit's cost curve,
      THEN

        Calculate the number of permits the unit receives under the uniform rollback allocation scheme

        Determine the number of permits the unit trades by calculating the difference between the number of permits the unit is allocated and the number of permits it requires for the IBEST compliance option. Add the absolute value of this quantity to the cumulative total of permits traded (CTRADE)

        Write the unit report 810.

        IF some action is necessary for compliance, THEN send construction and fuel data to the retrofit file.

    END IF

    After the last unit passes through the routine (LASTSW=1) write the market activity totals to report 810.
```

6a.3.2 Subroutine SORT

Called by:	COMPLY	
Calls:	None	
Arguments:	BASCST	- total annual levelized cost of fuel and pollution control devices for continued operation of a unit for its remaining life
	BASTPY	- tons of SO_2 emitted per year at the present level of pollution abatement (control option corresponding to BASCST)
	CSTINC	- average unit cost of SO_2 removal for the MARTRY compliance option
	CSTMAR	- marginal cost of pollution abatement for the MARTRY segment of a SO_2 abatement cost curve
	MARTRY	- number of the attempt made in obtaining a point on the SO_2 abatement cost curve (ranges in value from 1 to NOTRY)
	IUNSEQ	- unit sequence number

MKTNUM - market identification number assigned to a coal unit participating in the SO_2 permit market

NOTRY - total number of attempts made in generating points on a unit's SO_2 abatement cost curve (equals 1 by default, ranges from 3 to 5 for market simulation participants)

NPTDIS - number of segments composing a unit's convex cost curve

PRVCST - total annual levelized cost of operation (fuel and pollution control) for a discharger's control option with the greatest marginal cost

PRVTPY - annual SO_2 emissions level for the discharger's control option with the greatest marginal cost

SO2TPY - tons of SO_2 emitted per year for the MARTRY operating point

TONREM - increment tons of SO_2 removed for the MARTRY compliance option

TANCOS - total annual levelized cost of choosing the MARTRY operating point

VLIST - 33 operating characteristics of the MARTRY operating point

Tasks: For an SO_2 permit market using the demand curve technique:

1) To remove concavities in a unit's SO_2 abatement cost curve.

2) To store the characteristics of each operating point composing the convex cost curve in the OPCHAR array so that the characteristics of the compliance option can be placed in the retrofit files when control options are selected in subroutine GRANDF

Method:

```
IF this is the first segment of a unit's cost curve (MARTRY=1), THEN

        Assign the unit a market number

        Initialize all working arrays to zero

        Place the 33 operating characteristics in the next available position in the OPCHAR array

END IF
```

```
IF this is not the first segment of a unit's cost curve (MARTRY>1),
    THEN

    DO for each of the unit's cost curve segments previously stored in
        the OPCHAR array (NPTDIS) -starting with the last cost
        curve segment (NPTDIS-1).

        IF the marginal cost of the new control option is less than
        the marginal cost of the stored cost segment (NPTDIS-1),
        THEN

            Delete the stored cost segment from the OPCHAR
            array.

            Recalculate the marginal cost of the cost curve
            segment.

        END IF

    IF the marginal cost of the new control option is greater than the
    marginal cost of the stored cost segment, THEN insert the pollu-
    tion control characteristics in the next available position in the
    OPCHAR array.

    END DO

END IF
```

6a.3.3. Subroutine RANK

Called by: COMPLY

Calls: None

Arguments:

NOPART	-	number of plants participating in the market
MKTNUM	-	market identification number assigned to a coal unit participating in the SO_2 permit market
NPTDIS	-	number of segments composing a unit's convex cost curve

Tasks: Form the permit demand curve for the system by placing each segment of a unit's convex cost curve in a merit-order ranking based on increasing marginal cost of pollution abatement options for the system.

Method:

```
DO for each segment of a unit's cost curve

    DO for each segment of the permit demand curve

        IF the marginal cost of the cost curve
           segment is less than the marginal cost of the demand
           curve segment, THEN

            Move each permit demand curve segment down in
            the ranking hierarchy.

            Insert the cost curve segment in its position in the
            demand curve.

            Advance to the next cost curve segment.

        END IF

    END DO

END DO
```

6a.3.4. Subroutine GRANDF

Called by: COMPLY

Calls: None

Arguments:

ISTATE - state FIPS code

IYEAR - simulation year

MGTSW - pollution control management switch

NOPART - number of coal units participating in the SO_2 permit market

Tasks: Determines the SO_2 pollution control compliance strategy of each coal unit participating in the SORT market. Construction and compliance fuel characteristics are placed in the retrofit file for units that reduce their emissions under the market program. Permits are allocated to each unit based on a uniform rollback of their projected SO_2 emissions. Market activity, tracking the behavior of each unit in the market, is written to unit 80.

Method:

```
DO for each segment composing the permit demand curve (until the level
    of $SO_2$ emissions based on the compliance options selected is less than
    the emissions cap and the marginal cost of pollution control is greater
    than zero):

        Determine the market participant corresponding to the compliance
        option representing the demand curve segment.

        Place in IPOS array, in position MKTNUM (corresponding to the
        demand curve segment), the location in the OPCHAR array of the
        compliance option corresponding to the demand curve segment.

        Calculate the total level of $SO_2$ emissions for the system of
        dischargers assuming each unit were operating at the compliance
        options listed in the IPOS array.

END DO

DO for each market participant

        Calculate the number of permits the unit is allocated based on the
        uniform rollback corresponding to the emissions cap divided by
        the projected level of $SO_2$ emissions for the system.

        Calculate the number of permits a unit requires for the pollution
        control option listed for the unit in the IPOS array
        Determine the number of permits the unit trades by calculating the difference between the allocation and the number of permits needed by the unit. Add the absolute value of this quantity to the number of permits traded in the state

        Write Report 810 to tape 80 for the unit

        IF the unit undergoes some form of compliance in the market, THEN send the construction and fuel data to the retrofit files.

    END DO

    Write the cumulative report totals for Report 810.
```

6a.4 Variable Definitions

Table 6a-1 is a supplemental list of variable definitions for the Scan of the Unit Inventory section of the COMPLY subroutine. A dictionary of other variables in the pollution control module can be found in Table C6-1 of the pollution control module, Chapter C6.

Table 6a-1

TDP POLLUTION CONTROL VARIABLE DESCRIPTIONS

Variable	*Unit*	*Location*	*Description*	*Accessed by*
AVASH	Fraction		Average ash content of a compliance coal	COMPLY
AVHHV	Btu/lb		Average HHV of a compliance coal	COMPLY
AVSUL	Lb/MMBtu		Average sulfur content of a compliance coal	COMPLY
BASCST	$/yr		Total annual levelized cost of fuel and pollution control devices for continued operation of a unit for its remaining life	COMPLY,FUTURS SORT
BASTPY	Tons/yr		Projected annual SO_2 emission level at the present level of pollution abatement	COMPLY,FUTURS, SORT
CSO2RM	Tons/yr		Cumulative amount of SO_2 removed by a unit attributable to the selection of a pollution control strategy in a market system	FUTURS,GRANDF, SORT
CSTINC	$/yr		Average unit cost of SO_2 emission reduction for a point on a cost curve	COMPLY,SORT
CSTMAR	$\delta\$ / \delta ton$		Marginal cost of SO_2 emission reduction (the slope segment of a of a cost curve)	COMPLY,FUTURS, GRANDF,SORT
CTRADE	Tons/yr		The number of permits sold by units in a market system, defined as half the sum of the absolute values of the difference between initial and final permit holdings	FUTURS,GRANDF
DELTAS	$\frac{\delta lb}{MMBtu}$		Incremental change in the SO_2 standard between points on the cost curve	COMPLY
EMISCP	Tons/yr	/TDPCNL/	Emissions cap for market participants used by SORT in determining the treat/buy partition of the permit demand curve	COMPLY,GRANDF

Table 6a-1 (contd.)

Variable	*Unit*	*Location*	*Description*	*Accessed by*
ENERGY	MWh		The projected average annual energy output of a unit	COMPLY
FEATUR			Array holding the characteristics of the optimal pollution control strategy for a unit in a FUTURS market (1-9) SO_2 retrofit data (10-18) TSP retrofit data (19-27) NO_x retrofit data (28-33) Compliance fuel data	FUTURS
FMGTSW			Real equivalent of MGTSW	GRANDF
FRERED	Tons/yr		Tons of SO_2 removed at a cost savings due to the inferiority of base operating points	FUTURS,GRANDF
FSEQ			Real equivalent of IUNSEQ	FUTURS,GRANDF
FTVCPC	$/yr		The annual variable pollution control cost component of the base operating point	COMPLY
IBEGIN			Location in the IPOS array to insert a compliance option into the demand curve ranking	SORT,RANK
IBEST			The segment of a unit's cost curve representing the best pollution control option to select in a market system	FUTURS
IEND			Location in the IPOS array of the last cost curve segment composing the permit demand curve	SORT,RANK
ILAST			The total number of steps on the system demand curve	RANK
ILOC	Integer	//	Location in the OPCHAR array for the first segment of a discharger's cost curve	GRANDF,RANK, SORT
INRANK			Location in the IPOS array indicating a compliance option's new ranking in the system demand curve	RANK

Table 6a-1 (contd.)

Variable	*Unit*	*Location*	*Description*	*Accessed by*
IOPRPT			Location in the OPCHAR array of the characteristics of each unit's optimal pollution control option in a SORT market	GRANDF
IPOS		//	Location in the OPCHAR array of the ith step of the permit demand curve	GRANDF,RANK
IPREV			Location of a cost curve segment having the greatest marginal cost	SORT
IRANK			Do loop index for each step of the permit demand curve	GRANDF,RANK
IREGCT	Codelist 1		Regulatory category for pollution control	COMPLY,FUTURS, GRANDF,SORT
ISIPSW			Switch=1 in decision year under an SIP rollback management program simulation (=0 by default)	COMPLY
ITOPTS		/TDPCNL/	The total number of steps composing the system-wide demand curve	COMPLY,GRANDF, RANK,SORT
ITRAPD		/TDPCNL/	Switch=1 in decision year of a market program (=0 by default)	COMPLY
IYRDX			Location of the applicable permit price in TDPRIC array	FUTURS
LASTSW			Switch=1 indicating the final call to FUTURS to write the cumulative total to report 810 (=0 by default)	COMPLY,FUTURS
MARTRY			The number of the attempt at obtaining a point on the SO_2 abatement cost curve ($0 \leq$ MARTRY $\leq$ NOTRY)	COMPLY,FUTURS, SORT
MGTSW			Management program switch 0 - no program (default) 1 - SIP Rollback	COMPLY,GRANDF

Table 6a-1 (contd.)

Variable	*Unit*	*Location*	*Description*	*Accessed by*
			2 - FUTURS Market 3 - SORT Market	
MKTNUM			Market identification number assigned to a coal unit participating in the SO_2 permit market	COMPLY,FUTURS, GRANDF,RANK,SORT
MKTYR		/TDPCNL/	The year a management program controlled by MGTSW is to be implemented	COMPLY
NOCURP			Index for a point of the demand curve	RANK
NOPART			Number of coal plants eligible to participate in the market	COMPLY,GRANDF, RANK
NOTRY			The total number of attempts made at generating points on a discharger's SO_2 abatement cost curve (max = 5)	COMPLY,FUTURS, SORT
NOXDVI	Codelist F		Temporary variable for the existing NO_x device	COMPLY
NPTDIS			The number of segments composing a unit's convex cost curve	COMPLY,RANK, SORT
OPCHAR		//	SORT pollution control compliance characteristics array dimension 1 - control option for the system dimension 2 - operating characteristics position 1-9 - SO_2 Retrofit Data position 10-18 - TSP Retrofit Data position 19-27 - NO_x Retrofit Data position 28-33 - Compliance Fuel Data position 34 - CSTINC position 35 - TONSREM position 36 - CSTMAR position 37 - MKTNUM	GRANDF,RANK, SORT

Table 6a-1 (contd.)

Variable	*Unit*	*Location*	*Description*	*Accessed by*
PERALL	Tons/yr		SO_2 permits required by a unit for the optimal market system control strategy	FUTURS,GRANDF
PEREMP	Fraction		Reduction in emissions for a point on a unit's SO_2 abatement cost curve	FUTURS
PERGIV	Tons/yr		SO_2 permits given to a unit based on the grandfathering scheme	FUTURS,GRANDF
PEROLL	Fraction	/TDPCNL/	Rollback fraction used to allocate SO_2 permits in a FUTURS market and to reduce SIP emissions standards in an SIP rollback simulation	COMPLY,FUTURS
PERREM	Fraction		Optimal emission reduction level chosen by a unit participating in an SO_2 permit market	FUTURS,GRANDF, SORT
PRVCST	$/yr		Total annual levelized cost of operation (fuel and pollution control) for a discharger's control option with the greatest marginal cost	COMPLY,FUTURS, SORT
PRVTPY	Tons/yr		Annual SO_2 emissions level for the discharger's control option with the greatest marginal cost	COMPLY,FUTURS, SORT
REQRED	Fraction		Level of emission reduction for the system dictated by the emission cap, used to allocate permits in the SORT method	GRANDF
RMNOXI	Fraction		Temporary variable for existing NO_x removal efficiency	COMPLY
SO2EMI	Tons/yr	//	Projected uncontrolled annual emissions level of an SO_2 market participant	GRANDF,SORT
SO2NMW	Lb/MMBtu		SO_2 emission rate for a potential control strategy	

Table 6a-1 (contd.)

Variable	*Unit*	*Location*	*Description*	*Accessed by*
SO2REM	Ton/yr		The amount of SO_2 removed by a unit by operating at the control option selected in a market	GRANDF
SO2RMI	Fraction		Temporary variable for the existing SO_2 removal efficiency	COMPLY
SO2SDI	Lb/MMBtu		Temporary variable for the existing SO_2 standard	COMPLY
SO2TPY	Ton/yr		Annual SO_2 emissions for a point on the SO_2 abatement cost curve	COMPLY,FUTURS, GRANDF,SORT
TALLO	Tons/yr		Cumulative total of the number of permits grandfathered in a state under the SORT market	FUTURS,GRANDF
TANCOS	\$/yr		Annual levelized cost (fuel and pollution control) of a pollution control option for a single unit	COMPLY,FUTURS, SORT
TDPRIC	\$/ton	/TDPCNL/	Price for securing an SO_2 permit for the various time periods in the MPMS analysis	FUTURS
TDPYRS	Years	/TDPCNL/	Simulation years corresponding to the ith permit price in the TDPRIC array	FUTURS
TFALLO	Tons/yr		Cumulative number of SO_2 permits exercised by all dischargers in a market system	FUTURS,GRANDF
TONREM	Tons/yr		Incremental amount of SO_2 removed between points on a unit's SO_2 abatement cost curve	COMPLY,SORT
TOTSAV	\$/yr		Savings incurred by a unit by purchasing permits as opposed to reducing emissions	FUTURS
TOTSO2	Tons/yr	/TDPCNL/	Projected uncontrolled total annual SO_2 emissions for market participants	FUTURS,GRANDF, SORT

Table 6a-1 (contd.)

Variable	*Unit*	*Location*	*Description*	*Accessed by*
TRADE	Tons/yr		The difference between the number of permits given to a unit and the optimal permit allocation	FUTURS,GRANDF
TSPDVI	Codelist D		Temporary variable for existing TSP device	COMPLY
TSPRMI	Fraction		Temporary variable for the existing TSP removal efficiency	COMPLY
TVCPCO	$/KWh		Temporary variable for the unit's variable cost associated with pollution control	
YROFF	Year		Retirement year used in levelizing pollution control costs when capacity factor data projects an early retirement	

C7. THE DISPATCHING MODULE

by
N. Tyle, S.N. Talukdar and R. Edahl

Universities Research Group on Energy
Carnegie-Mellon University

7.1 Overview

Dispatching is the process of allocating a demand for electric energy among generators designated to meet that demand. The principle quantities of concern in making the allocation are (1) the net operating cost of the generators and (2) the net contribution the generators make to various emission categories (sulfur dioxide, oxides of nitrogen and total suspended particulates).

The purpose of the dispatching module is to find the allocation that minimizes a selected quantity of concern while meeting constraints on the other quantities of concern and keeping in the operating ranges of the generators. It is assumed that the dispatching module will be used to find the least-cost solution while maintaining regional limits on various emissions. The module can also be used to find the least sulfur dioxide (SO_2) emission solution, while maintaining regional limits on the other emissions and on the total cost of the generating unit.

Dispatching is usually performed for a state during a given year. The load forecast for the year is given in the form of a discrete load duration curve (LDC). (The load duration curve consists of three segments that correspond to the peak, base and average loads.)

7.2 Central Algorithms and Basic Assumptions

Two algorithms are available for the formulation and the solution of the dispatch problem. If no emission constraints are imposed, a merit-ordering algorithm is satisfactory. In the presence of emission constraints, a constrained optimization procedure is needed.

7.2.1 Merit-Order Dispatching

Merit-order dispatching is a greedy strategy that has been used in other models, such as the Utility Simulation Model. It was coded as an interim tool to serve while the linear programming model was being developed.

The purpose of the merit-order dispatching is to allocate generation to meet load demand without violating any availability or capacity factor constraints and at the minimum cost. The merit-order dispatching cannot handle regional emission constraints.

The following assumptions are made in coming up with the merit-order formulation:

1. The load duration curve can be approximated by a continuous curve between the peak and the base load.

2. Delivery losses (the transmission and distribution [T&D] network) can be lumped and added to the net demand as seen by the generating network. In essence, all generators are connected to a single node with the net load.

3. All energy shortfalls are assumed to energy purchases at a cost equal to 105 percent of the cost of the most expensive generator.

4. Forced outages (availability factor constraints) are modeled by derating the full load capacity.

5. It is assumed that all the characteristics of the fuel used for each generator are given. No fuel selections are made by the dispatching module.

6. The cost of producing a unit of electricity (one megawatt hour [MWh] from a generator are known and are constant for the full period. The amounts of emissions produced per MWh are constant for each generator and are computed in COMPLY, a component of the pollution control module.

In this algorithm, the generators are arranged in ascending order of their operating and maintenance (O&M) costs. The cheapest generator is assigned to take as much load as its rating and its capacity factor allow. The next cheapest is then deployed, and so on. If there are any energy shortfalls, it is assumed that they are made up by energy purchases. For more details, see the analytical documentation [1].

7.2.2 Linear Programming Dispatching

In its other mode, dispatching is formulated as a linear programming (LP) problem and solved using the revised simplex method implemented in the XMP linear programming package [2]. The following assumptions are made in coming up with the LP formulation:

1. The load duration curve can be approximated by discrete steps. In support of this assumption, we know that little information is available on the shape of the load duration curve so that using a stepped approximation will not compromise the fidelity of the input data.

2. Delivery losses (from the T&D network) can be lumped and added to the net demand as seen by the generating network. In essence, all generators are lumped into one single node with the net load.

3. Either the amount or the unit costs of interregional energy exchanges are known. If the amount is known, it is included in the net load duration curve. If the cost is known, then interregional transfers are modeled by a "fictitious" generator.

4. For energy shortfalls, a fictitious generator is introduced with a cost equal to 105 percent of the cost of the most expensive generator. This generator is assumed to have a high emission coefficient, when least-emission dispatching is being performed.

5. Forced outages (availability factor constraints) are modeled by derating the full load capacity.

6. It is assumed that all the characteristics of the fuel used for each generator are given. No fuel selections are made by the dispatching module.

7. The cost of producing a unit of electricity (one megawatt hour) from a generator are known and are constant for the full period. The amounts of emissions produced per MWh are constant for each generator and are computed in COMPLY, a component of the pollution control module (see Chapter C6).

The objective of the LP dispatching formulation is to minimize either total operating cost or total emissions of a given pollutant, subject to three kinds of constraints. First, load demand for each segment of the load duration curve must be met. Second, regional emission constraints for each pollutant must be met. Third, all pieces of equipment (generators and control technologies) must be operated within their specified ranges and must meet their availability and capacity factor constraints. For some units, this is done by the explicit inclusion of these constraints. For most units, however, this is done by using simple upper bounds on the operating levels, which ensure that the capacity factor and availability constraints are not violated.

7.3 Data Handling

7.3.1 Input/Output Information

Data groups 15, 21, 42, and 70 are the major sources of input and output in the dispatching modules.[1] Data group 15 provides electric load information. Net energy demand in billion KWh (DEMAND(1)) and peak load in MW (DEMAND(2)) are obtained by GET. The cost of emergency energy purchases in million dollars (DEMAND(8)) is written by PUT. Data group 21 contains information on T&D and general O&M costs. This information (PLAN(4:6)) is obtained by using GET. Consolidated costs are output to data group 42. The variables pertaining to the costs (COST(1:9)) are written using PUT.

Data group 70 gives generator and fuel information.

The linear programming-based dispatching module also uses scenario parameter 67 (a least-cost or least-emission dispatch). Regional emission limits for the pollutants are read from parameters 528, 529, and 530.

7.3.2 Output Reports from Dispatching

The dispatching modules produce three reports. Report 102 is a demand summary; report 410, a summary of annual fuel and operating costs; and report 420, a summary of generation.

7.4 Subprogram Descriptions

DSPACH and two auxiliary subroutines are the only permanent subprograms in the dispatching module. In the case of the merit-order algorithm, this is the only program module. In the case of the linear programming algorithm, several other subprograms exist to implement the LP formulation and solution procedure. These remaining subprograms can be changed, if a different LP package is implemented. Therefore, attention will be paid mostly to a detailed description of the DSPACH subprogram. At present, the LP package used to solve the problem is the XMP linear programming library. This report does not describe the individual XMP subprograms in detail, but synopses of these programs are given in Table C7-1; their calling sequences are given in Table C7-2.

---

[1] I.e., the merit-order and LP dispatching modules.

Description of the two DSPACH subprograms appear below:

7.4.1 Merit-Order Dispatching

Called by: Control Program

Calls: GET, GETSCN, ERROR, PUT, SPUT

Arguments: ISTATE, IYEAR, ITRACE

Task: Dispatches generators to meet electricity demand using a merit-order dispatch algorithm.

Method: This module dispatches all available units in an ascending order of operating cost, for a least-cost result. First, information on all available units (and their characteristics) is obtained by a scan of the unit inventory file in data group 70. This provides the total number of dispatchable units. Information on load demand is also obtained from the appropriate data group, as is information on loss factors. After ordering the generators in ascending order of their operating cost (in dollars per MWh), each operator is allowed to produce as much energy as possible. If the total load is not met, the remaining demand is met by purchasing power at a cost of 105 percent of the cost of the most expensive generator. The results are consolidated into several reports (reports 102, 410, and 420).

7.4.2 Linear Programming Dispatching

Called by: Control Program

Calls: GET, GETSCN, ERROR, PUT, SPUT, XMAPS, XADDAJ, XADDUB, XSLACK, XPRIML, AVL, VALUE

Arguments: ISTATE, IYEAR, ITRACE

Task: Dispatches generators to meet electricity demand. This subprogram sets up the LP formulation, which is then solved by other subprograms.

Method: This module sets up a linear programming formulation for least-cost or least-emissions dispatching of electric power generators in year IYEAR for the state ISTATE. First, information on all available units (and their characteristics) is obtained by a scan of the unit inventory file in data group 70. This provides the total number of dispatchable units. An extra emergency unit is then characterized. Information on load demand and emission scenarios is also obtained from appropriate data groups, as is information on loss factors. Using different LP subprograms (XMAPS, XADDAJ, XADDUB), the simplex tableau is generated for the LP problem in a sparse form, using bounds generated by subroutine AVL. Once the problem formulation is complete and without error (for example, no overflow of space or number, and no duplication), subprograms XSLACK and XPRIML are called to perform the actual optimization. Results are obtained by calling VALUE. The results are consolidated into several reports (Reports 102, 410, and 420).

7.4.2.1 Subroutine AVL

Name: AVL

Called by: DSPACH

Calls: None.

Arguments: AVAIL, AVM, CF, DLOAD, HOURS, IENG, JMAX, KJM

Task: For use in computing upper bounds for the generating units.

Method: For a single unit, AVM returns the array of maximum fractional operating levels for the segments of the duration curve. (These numbers are multiplied by the generator size in DSPACH to determine the upper bounds.) For IENG=1, the elements of AVM are set to AVAIL, the availability. For IENG=0, the elements of AVM are chosen so that, if possible, the first KJM elements are equal to AVAIL, and the remaining JMAP-KJM elements are proportional to the corresponding elements of DLOAD. No element of AVM may exceed AVAIL, and the elements are chosen so that the capacity factor constraint would be satisfied at equality if the unit were operated at the upper bounds.

7.4.2.2 Subroutine VALUE

Name:	VALUE
Called by:	DSPACH
Calls:	XGETUB
Arguments:	BNOTYP, IOERR, J, LENMA, LENMY, MAPA, MEMORY, STATUS, XBZERO
Task:	To compute the value of the j^{th} solution variable upon return from XMP.
Method:	VALUE is a modification of subroutine XPRINT in the XMP package.

7.5 Flowcharts

Flowcharts of the DSPACH programs appear in Figures C7-1 and C7-2.

7.6 Dictionary of Variables

Table C7-3 describes the variables used in the main program, DSPACH, including the units in which each variable is expressed. Further information is provided in Table C7-4, where the type, dimension, and source or destination of data are given for these same variables. Variables in the XMP linear programming package are summarized in Table C7-5. Finally, Table C7-6 describes the variables used in DSPACH to call the XMP programs, whose values must be assigned in DSPACH. For the most part, these values depend on the size of the problem.

Figure C7-1
MERIT-ORDER FLOWCHART

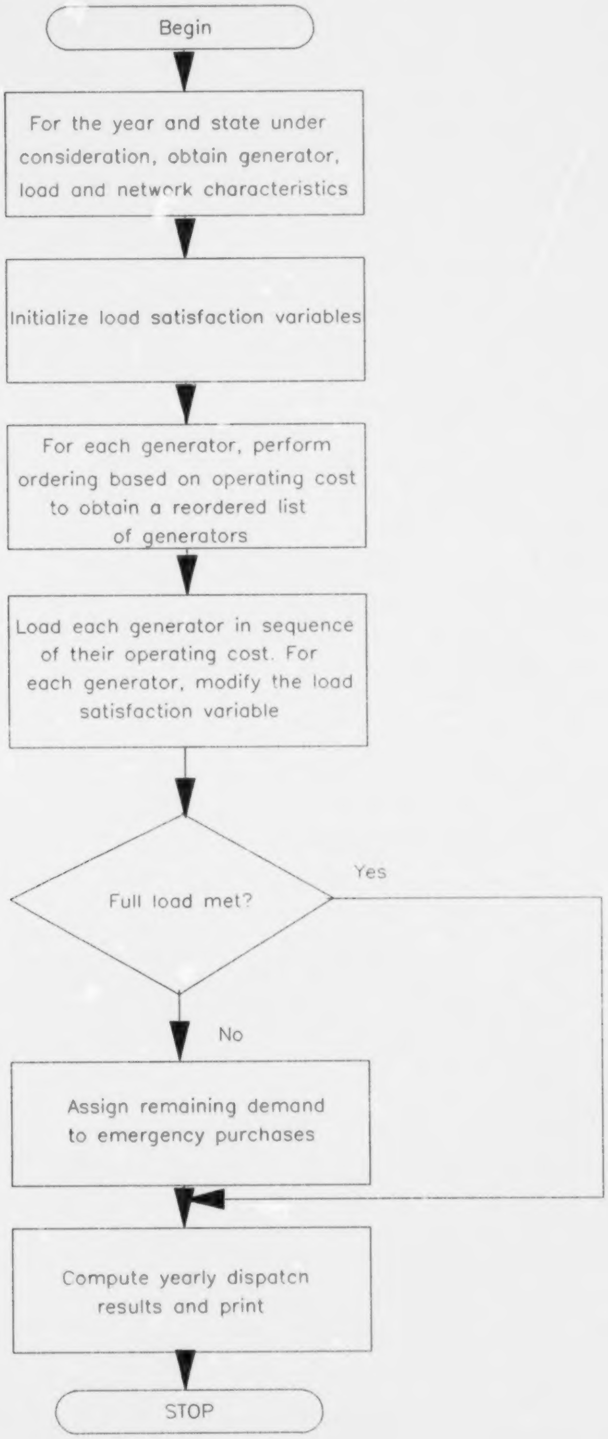

Begin
For the year and state under consideration, obtain generator, load and network characteristics
Initialize load satisfaction variables
For each generator, perform ordering based on operating cost to obtain a reordered list of generators
Load each generator in sequence of their operating cost. For each generator, modify the load satisfaction variable
Full load met?
Yes
No
Assign remaining demand to emergency purchases
Compute yearly dispatch results and print
STOP

Figure C7-2
LINEAR PROGRAMMING FLOWCHART

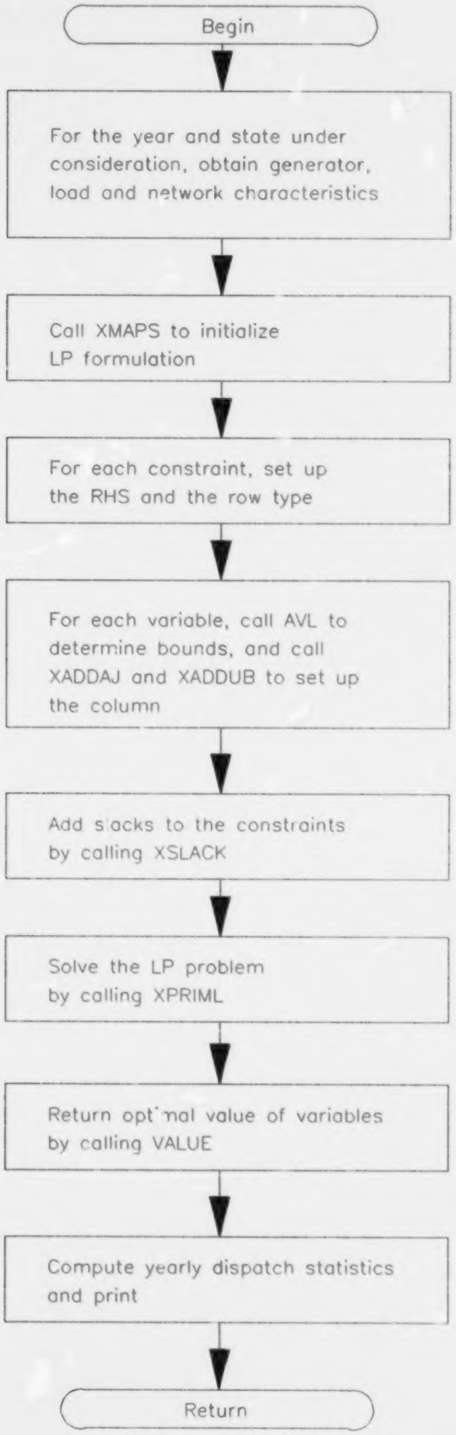

Begin
For the year and state under consideration, obtain generator, load and network characteristics
Call XMAPS to initialize LP formulation
For each constraint, set up the RHS and the row type
For each variable, call AVL to determine bounds, and call XADDAJ and XADDUB to set up the column
Add slacks to the constraints by calling XSLACK
Solve the LP problem by calling XPRIML
Return optimal value of variables by calling VALUE
Compute yearly dispatch statistics and print
Return

Table C7-1
SUBPROGRAM DESCRIPTIONS

Sub-program	Synopsis	Subroutines Called
	MAIN PROGRAM	
DSPACH	Formulates the problem of dispatching generators to meet the demand for electricity. In the linear programming version, this subprogram calls certain XMP subprograms to set up the LP problem and then to solve it	AVL, VALUE
	AUXILIARY PROGRAMS	
AVL	For the linear programming version, computes upper bounds for the operating levels of the generation units.	
VALUE	For the linear programming version, retrieves the XGETUB value of a solution variable. (VALUE is a modification of the XMP subroutine XPRINT.)	
	XMP SUBPROGRAMS	
	Category 1. Subprograms That Implement the Logic of the Simplex Method	
XBCOMP	Computes current values of basic variables and current value of objective function	XBREDU,XFTRAN,XSTOP
XBREDU	Reduces the right-hand side to account for the nonbasic variables at nonzero bounds	XGETAJ,XGETUB,XSTOP
XCAND	Constructs candidate list (list of attractive nonbasic variables eligible to enter the basis during the subsequent series of minor iterations)	XGETAJ,XDOT
XCHECK	Checks accuracy of current primal and dual solutions	XBREDU,XGETAJ
XCHUZR	Determines the variable to leave the basis for a primal simplex pivot	XPTIE,XSTOP
XDCHQ	Determines the variable to enter the basis for a dual simplex pivot	XGETAJ,XDOT,XSTOP
XDCHR	Determines the variable to leave the basis for a dual simplex pivot	XSTOP
XDOT	Computes the inner product between a row vector and a packed matrix column	None

Table C7-1 (contd.)

Subprogram	Synopsis	Subroutines Called
XDPH2	Executes phase 2 for the dual simplex method	XDCHR,XDCHQ (or FDCHQ), XGETAJ,XFTRAN, XUPDAT, XGETUB,XUPDX,XLOG, XFACT,XBCOMP,XBTRAN
XDUAL	Top-level subprogram for the dual simplex method	XGETAJ,XDOT,XGETUB, XBCOMP, XDPH2,XFACT, XBTRAN,XCHECK,XSTOP
XFEAS	Starts from any given basis and finds a primal feasible basis, if one exists; used as phase 1 of the primal simplex method	XCAND (or FCAND), XDOT, XGETUB,XPIVOT,XBTRAN, XFACT,XBCOMP,XLOG,XSTOP
XPHAS2	Executes phase 2 of the primal simplex method	XCAND (or FCAND), XDOT, XGETUB,XPIVOT,XBTRAN, XFACT,XBCOMP,XLOG,XSTOP
XPIVOT	Pivots the chosen entering variable into the basis (primal simplex method)	XFTRAN,XCHUZR,XUPDAT, XUPDX
XPRIML	Top-level subprogram for the primal simplex method	XFEAS,XZCOMP,XBTRAN, XPHAS2,XFACT,XBCOMP, XCHECK,XSTOP
XPTIE	Resolves ties that arise during the ratio test for the primal simplex method (XCHUZR)	None
XSLACK	Sets up a starting basis with a slack variable for each less-than-or-equal constraint, a surplus variable for each greater-than-or-equal constraint, an artificial variable (with both bounds zero) for each equation, and a free variable for each free row; used with XPRIML (which calls XFEAS) or XDUAL	XADDAJ,XADDUB,XFACT, XBCOMP,XSTOP
XSTART	Starts the primal or dual simplex method from any given basis	XGETAJ,XGETUB,XFACT, XBCOMP,XBTRAN,XSTOP
XUPDX	Updates the primal solution and the objective function value	None
XZCOMP	Computes the current value of the objective function	XGETAJ,XGETUB,XSTOP
FCAND	Fast version of XCAND: accesses the problem data structure directly	XGETAJ

Table C7-1 (contd.)

Sub-program	Synopsis	Subroutines Called
FDCHQ	Fast version of XDCHQ: accesses the problem data structure directly	XSTOP
Category 2. Subprograms That Serve as an Interface Between the Simplex Method and the Data Structure for the Problem Data		
XADDAJ	Adds a single column to the existing linear program	XDATA1
XADDUB	Adds bounds for a single variable	XDATA3
XGETAJ	Gets a single column from the existing linear program	XDATA2
XGETUB	Gets the bounds for a single variable	XDATA4
Category 3. Subprograms That Serve as an Interface Between the Simplex Method and the Data Structure for the Basis Inverse Representation		
XBTRAN	Performs the "Backward Transformation" (row vector * basis inverse)	LA05B,XSTOP
XFACT	Refactors (or reinverts) the current basis	XGETAJ,XLA05X,LA05A, XSTOP
XFTRAN	Performs the "forward transformation" (basis inverse * column vector)	LA05B,XSTOP
XUPDAT	Updates the current factorization (or inverse) of the basis	LA05C,XSTOP
Category 4. Subprograms That Manage the Data Structure for the Problem Data		
XDATA1	Adds a single column to the problem data structure (called by XADDAJ)	XSTOP
XDATA2	Retrieves a single column from the problem data structure (called by XGETAJ)	XSTOP
XDATA3	Adds bounds for a single variable to the problem data structure (called by XADDUB)	XSTOP
XDATA4	Retrieves the bounds for a single variable from the problem data structure (called by XGETUB)	XSTOP

Table C7-1 (contd.)

Sub-program	Synopsis	Subroutines Called
	Category 5. Subprograms That Manage the Basis Inverse Representation	
LA05A	Factors the basis into L and U factors (called by XFACT)	
LA05B	Performs both the "backward" and "forward" transformation operation (called by XBTRAN and XFTRAN)	
LA05C	Updates the factorization of the basis after a column exchange (called by XUPDAT)	
/LA05D/	Labeled common area for numerical constants	
LA05E	List compressor (called by LA05A and LA05C)	
MC20A	Sorting program (called by LA05A)	
XLA05X	Extra subprogram for interfacing the LA05A subprogram with XMP (called by XFACT)	XSTOP
	Category 6. Subprograms That Provide Miscellaneous Support Services	
XCONSA	Sets constants in the data structure for the problem data (called by XMAPS)	None
XCONSI	Sets constants in the data structure for the basis inverse representation (called by XMAPS)	None
XLOG	Prints log information after each pivot, if requested	None
XMAPS	Sets up the map of the data structure for the problem data (MAPA) and the map of the data structure for the basis inverse representation (MAPI); must be the first XMP subprogram called by the user program	XCONSA,XCONSI,XSTOP
/XMPCOM/	Labeled common area for numerical constants	
XSTOP	Provides for centralized handling of all fatal errors	None

Table C7-2
SEQUENCE OF CALLS IN THE XMP PACKAGE

Subprogram	Subprograms Called
XADDAJ	XDATA1
XADDUB	XDATA3
XBCOMP	XBREDU,XFTRAN,XSTOP
XBREDU	XGETAJ,XGETUB,XSTOP
XBTRAN	LA05B,XSTOP
XCAND	XGETAJ,XDOT
XCHECK	XBREDU,XGETAJ
XCHUZR	XPTIE,XSTOP
XCONSA	None
XCONSI	None
XDATA1	XSTOP
XDATA2	XSTOP
XDATA3	XSTOP
XDATA4	XSTOP
XDCHQ	XGETAJ,XDOT,XSTOP
XDCHR	XSTOP
XDOT	None
XDPH2	XDCHR,XDCHQ (or FDCHQ),XGETAJ,XFTRAN,XUPDAT,XGETUB,XUPDX,XLOG, XFACT,XBCOMP,XBTRAN
XDUAL	XGETAJ,XDOT,XGETUB,XBCOMP,XDPH2,XFACT,XBTRAN,XCHECK,XSTOP
XFACT	XGETAJ,XLA05X,LA05A,XSTOP
XFEAS	XCAND (or FCAND),XDOT,XGETUB,XPIVOT,XBTRAN,XFACT,XBCOMP,XLOG,XSTOP
XFTRAN	LA05B,XSTOP
XGETAJ	XDATA2
XGETUB	XDATA4
XLA05X	XSTOP
XLOG	None
XMAPS	XCONSA,XCONSI,XSTOP
XPHAS2	XCAND (or FCAND),XDOT,XGETUB,XPIVOT,XBTRAN,XFACT,XBCOMP,XLOG,XSTOP
XPIVOT	XFTRAN,XCHUZR,XUPDAT,XUPDX
XPRIML	XFEAS,XZCOMP,XBTRAN,XPHAS2,XFACT,XBCOMP,XCHECK,XSTOP
XPTIE	None

Table C7-2 (contd.)

Subprogram	Subprograms Called
XSLACK	XADDAJ,XADDUB,XFACT,XBCOMP,XSTOP
XSTART	XGETAJ,XGETUB,XFACT,XBCOMP,XBTRAN,XSTOP
XSTOP	None
XUPDAT	LA05C,XSTOP
UPDX	None
XZCOMP	XGETAJ,XGETUB,XSTOP
FCAND	XGETAJ
FDCHQ	XSTOP

Table C7-3

DSPACH VARIABLE DESCRIPTIONS

Variable	Unit	Description
ISTATE		FIPS state code
IYEAR		Year
ITRACE		Level of program trace
AVAIL(I)		Availability factor of generator I
BLOAD	MW	Base load
C(I)	$/MWh	O&M cost of generator I
CFMAX(I)		Maximum capacity factor of generator I
COLCOS(I)	Cents/MMBtu	Fuel cost of fuel I
COST(1)	Million $	Fuel cost for coal generators
COST(2)	Million $	Fuel cost for nuclear generators
COST(3)	Million $	Fuel cost for distillate oil generators
COST(4)	Million $	Fuel cost for residual oil generators
COST(5)	Million $	Fuel cost for natural gas generators
COST(6)	Million $	Fuel cost for other generators
COST(7)	Million $	Total O&M cost, all generators
COST(8)	Million $	Total O&M cost, pollution control
COST(9)	Million $	Total T&D cost, pollution control
DEMAND(1)	Billion KWh	Total energy required
DEMAND(2)	MW	Peak load
DEMAND(8)	Million $	Cost of net purchases
DLOAD(J)	MW	Load demand in Jth segment of load duration curve
E(I,K)	Lb/MWh	Emission coefficient for generator I for pollutant K
EMAX(K)	Lb/yr	Regional emission constraint on pollutant K
ENERGY(I)	GWh	Energy output of generator I; output to report 420
EPP	Million $	Emergency power cost
GEN(I)	MW	Generator I capacity
HEATRT(I)	Btu/KWh	Heat rate of generator I
HHV(I)	*Btu/quantity*[3]	Higher heating value of fuel for generator I
HOURS(J)	Hours	Duration of segment J of load duration curve
IST		Code for the least-cost/least-emission option (1 - least cost, 2 - least SO_2)

Table C7-3 (contd.)

Variable	Unit	Description
ITYP(I)	Codelist I	Fuel type used by generator I[b]
JMAX		Number of segments in load duration curve (= 3 in model)
KMAX		Number of regional emission constraints (= 3 in model)
NDSPCH		Number of generators dispatched
NUNITS		Total number of generators in group 70
NSCHED		Total number of generators in inventory
OMCOST(I)	$/MWh	O&M cost of generator I
PLAN(4)	$/KW	Transmission O&M cost
PLAN(5)	$/KWh	Distribution O&M cost
PLAN(6)	$/KWh	General O&M cost
SEQ(I)		Generator sequence number
TEMP(1)		Generator sequence number
TEMP(2)		Current capacity factor
TEMP(3)	GWh	Current energy output
TEMP(4)		Total fuel consumed for the year
	1000 tons	for ITYP = 1
	1000 barrels	for ITYP = 2,3
	1000 cubic feet	for ITYP = 4
	MMBtu (thermal)	for ITYP = 6
TEMP(5)	Tons/day	Coal used for coal generators
TOTCAP(I)	MW	Total capacity in fuel category I[c]; output to report 420
TOTCF(I)		Capacity factors for fuel category I; output to report 420
TOTGEN(I)	GWh	Total energy output for fuel category I; output to report 420
TVCPP(I)	$/KWh	Variable pollution cost of generator I
UNIT(.)	Different	Temporary storage for several generator characteristics

---

[a] See the AUSM system design document for units [3].

[b] 1=coal; 2=residual oil; 3=distillate oil; 4=gas; 5=gasoline; 6=nuclear; 7=other; 0=no data.

[c] See the description of codelist I in the system design document [3].

Table C7-4

DSPACH VARIABLE INFORMATION

Variable	Type	Dimension	Data Source or Destination
ISTATE	Integer	1	Argument
IYEAR	Integer	1	Argument
ITRACE	Integer	1	Argument
AVAIL(I)	Real	400	Data group 70[a]
BLOAD	Real	1	
C(I)	Real	400	
CFMAX(I)	Real	400	Data group 70[a]
COLCOS(I)	Real	400	Data group 70[a]
COST	Real	9	Data group 42[b]
DEMAND	Real	8	Data group 15[c]
DLOAD(J)	Real	3	
E	Real	400, 3	Data group 70[a]
EMAX	Real	3	GETSCN(528-530)[d]
ENERGY	Real	400	
EPP	Real	1	
GEN	Real	400	Data group 70[a]
HEATRT	Real	400	Data group 70[a]
HHV	Real	400	Data group 70[a]
HOURS	Real	3	Calculated internally
IST	Integer	1	Code for least-cost/least-emission option from GETSCN(67)
ITYP	Integer	400	Data group 70[a]
JMAX	Integer	1	
KMAX	Integer	1	
NDSPCH	Integer	1	
NUNITS	Integer	1	
OMCOST	Real	400	Data group 70[a]
PLAN	Real	8	Data group 21[a]
SEQ	Real	400	Data group 70[a]
TEMP	Real	9	
TOTCAP	Real	7	
TOTCF	Real	7	

Table C7-4 (contd.)

Variable	Type	Dimension	Data Source or Destination
TOTGEN	Real	7	
TVCPP	Real	400	Data group 70[a]
UNIT	Real	72	Data group 70[a]

[a] Input variable.

[b] Output variable.

[c] Both input and output variable.

[d] GETSCN.

Note: See Reference 3 for descriptions of codelists and data groups. GETSCN means scenario parameter.

Table C7-5

XMP VARIABLES

Variable	Synopsis
ACOEFF	Part of the problem data structure; contains the nonzero coefficients
B	Right-hand-side array
BASCB	Array containing the objective function coefficients of the basic variables
BASIS	List of basic variables
BASLB	Array containing the lower bounds on the basic variables
BASUB	Array containing the upper bounds on the basic variables
BETAR	Holds row R of the basis inverse, where R is the position of the variable BASIS(R) that is leaving the basis
BLOW	Contains the lower limit for each two-sided constraint (upper limit is in B)
BNDTYP	1 means lower bound = 0, upper bound = + infinity for every nonfree variable; 2 means lower bound = 0, upper bound = bound for every nonfree structural variable; 3 means lower bound = 0 for every nonfree variable; 4 means both bounds are general
BOUND	Common upper bound when BNDTYP = 2
CAND	Candidate list; contains the nonbasic variables that are eligible to enter the basis during a series of minor iterations
CANDA	Table containing the nonzero coefficients of columns that belong to candidate list
CANDCJ	List containing the objective coefficient for each column that belongs to candidate list
CANDI	Table containing the row numbers corresponding to the nonzeros of the columns that belong to the candidate list
CANDL	List containing the number of nonzeros in each column that belongs to the candidate list
CJ	Holds one objective function coefficient
COLA/VAL	Holds nonzero coefficients of a matrix column
COLI/IRO	Holds the row numbers corresponding to the nonzeros of a matrix column
COLLEN	Holds the number of nonzeros in a matrix column
COLMAX	Maximum number of nonzeros in any matrix column

Table C7-5 (contd.)

Variable	Synopsis
COLPNT	Part of the problem data structure; contains a pointer to the beginning of the section for each column in the ACOEFF and ROWNOS arrays
DERROR	Output by XCHECK: the absolute value of the maximum dual residual
DFEASQ	If a dual infeasible column is detected during the dual simplex method, then DFEASQ is the index of the corresponding primal variable
DINDEX	Output by XCHECK: the index of the column where the maximum dual residual occurs
DOK	Output by XCHECK: .true. means current solution passes the dual accuracy test; .false. means it fails
DQ	"Relative profit" or "reduced profit" of the entering variable
DTERM	Termination code for the dual simplex method: 1 means optimal solution found; 2 means the dual is unbounded; 3 means dual feasibility lost; 4 means the presumed optimal solution does not satisfy the accuracy check; 5 means that it was not possible to make a dual feasible start
DTOLER	Input for XCHECK: the tolerance for the dual accuracy check
DUNBR	If the dual problem is unbounded, the row in which the unbounded condition was detected
FACTIT	Number of iterations performed since the last factorization
FACTOR	Refactorization frequency
FCODE	Return code for XFACT: 1 means everything OK; 2 means some artificial variables have been inserted into the basis; 3 means storage overflow
FEAS	.true. if a feasible solution of the original problem has been found; .false. otherwise
INTYP	+ 1 means the entering variable is increasing from its lower bound; - 1 means the entering variable is decreasing from its upper bound
IOERR	I/O unit where error messages are to be written
IOLOG	I/O unit where log information is to be written if requested
J	Holds the index of a single variable
LAMBDA	Winning ratio from the dual ratio test
LEAVE	Index of the variable that leaves the basis when variable Q enters; LEAVE = Q if OUTTYP = 0, otherwise LEAVE = BASIS(R)

Table C7-5 (contd.)

Variable	Synopsis
LENMA	Length of the MAPA array
LENMI	Length of the MAPI array
LENMY	Length of the MEMORY array
LOOK	Number of matrix columns to be considered during construction of the candidate list
LOWERB	Part of the problem data structure; contains the lower bounds on the variables when BNDTYP = 4
LJ	Holds the lower bound on a single variable
LQ	Lower bound on the entering variable
M	Number of constraints
MAPA	Map of the data structure for the original problem data, consisting of pointers into the memory array
MAPI	Map of the data structure for the basis inverse representation, consisting of pointers into the memory array
MAXA	Maximum number of nonzeros that will be encountered in the whole constraint during the current run
MAXM	Maximum number of constraints that will be encountered during the current run; used to set array sizes
MAXN	Maximum number of variables that will be encountered during the current run; used to set array sizes
MEMORY	Main storage array; contains all arrays for the problem data and the basis inverse representation
N	Total number of variables (including slacks and artificials)
NTYPE2	If BNDTYP = 2, then each variable 1,2,...,NTYPE2 must either share the common upper bound or else be a free variable; each of the remaining variables NTYPE2 + 1,...,N must either have lower bound zero and upper bound + infinity or else be a free variable
NREJ	Number of entries in the reject list sent to XDCHR (see REJECT, below)
OUTTYP	+ 1 means the leaving variable is going to its lower bound; - 1 means the leaving variable is going to its upper bound; 0 means the entering and leaving variables are the same

Table C7-5 (contd.)

Variable	Synopsis
PCODE	Return code for XPIVOT: PCODE = - 1 if the pivot column rejected because the pivot element is too small; otherwise PCODE set equal to the value of UCODE returned by XUPDAT
PERROR	Output by XCHECK: the absolute value of the maximum primal residual
PHASE	Phase (1 or 2)
PICK	Size of the candidate list used for multiple pricing
PINDEX	Output by XCHECK: index of the row where the maximum primal residual occurs
PIVOT	Pivot element, PIVOT = YQ(R)
POK	Output by XCHECK: .true. means the current solution passes the primal accuracy test; .false. means it fails
PPRIME	Number of attractive nonbasic variables actually placed in the candidate list; PPRIME less than or equal to P
PRINT	Specifies the level of printing desired: 0 means error messages only; 1 means termination condition messages; 2 means print objective function value after each basis refactorization; 3 means log information at every iteration
PROFIT	Part of the problem data structure; contains the objective function
PTOLER	Input for XCHECK: the tolerance for the primal accuracy check
Q	Index of the entering variable
R	Position of the leaving variable, e.g., index of the variable leaving the basis is BASIS(R)
REJECT	List of rows that may not be chosen as the pivot row; an argument to XDCHR, part of the pivot rejection mechanism for the dual simplex method
ROWNOS	Part of the problem data structure; contains the row numbers corresponding to the nonzeros in the ACOEFF array
ROWTYP	Array of row types: + 2 means a two-sided constraint; + 1 means less than or equal to; 0 means equation; - 1 means greater than or equal to; - 2 means a free row (functional)
SCODE	Return code for XSTART: 1 means everything OK; 2 means the given basis was singular
START1	Starting column for the partial pricing procedure

Table C7-5 (contd.)

Variable	Synopsis
START2	Last column considered by the partial pricing procedure
STATUS	Indicator for each variable: 0 means the variable is out at its lower bound; K means that this is the Kth basis variable; - 1 means that this variable is out at its upper bound; - 2 means that this is a free variable (once in the basis it never leaves); - 3 means that this is an artificial variable (once it leaves the basis it never reenters); - 4 means the variable is locked out of the basis at its lower bound; - 5 means the variable is locked out of the basis at its upper bound (Note: free and artificial variables always have status - 2 or - 3, respectively; they do not get a positive status when they are in the basis)
TERMIN	Termination code for the primal simplex method: 1 means optimal solution found; 2 means problem is unbounded; 3 means the problem is infeasible; 4 means the presumed optimal solution does not satisfy the accuracy check
THETA	Amount of change in the variable entering the basis, i.e., the value of the winning ratio from the primal ratio test
UCODE	Return code for XUPDAT: 1 means everything is OK; 2 means refactorization suggested because the number of nonzeros has doubled; 3 means the current basis is singular; 4 means storage overflow; refactorization is imperative if UCODE is 3 or 4 (the current version of XUPDAT will return UCODE = 1 or stop with an error message)
UPPERB	Part of the problem data structure; contains the upper bounds on the variables when BNDTYP = 3 or 4
UJ	Holds the upper bound on a single variable
UQ	Upper bound for the entering variable
UZERO	Array containing the values of the dual variables
XBZERO	Array containing the values of the basic variables
YQ	Holds unpacked column that is about to enter the basis
Z	Value of the objective function
ZNB	Objective contribution of the nonbasic variables

Table C7-6

VARIABLES USED IN PROGRAM DSPACH TO CALL XMP PROGRAMS

Variable	Description
	Scaler Variables
COLMAX	Maximum number of nonzeros encountered in any single matrix column during the current run
FACTOR	Refactorization frequency
IOERR	I/O unit where error messages are written
IOLOG	I/O unit where log information is written if requested
LENMY	Length of the memory array
LOOK	Number of matrix columns to be scanned during construction of the candidate list; controls partial pricing
MAXA	Maximum number of nonzeros encountered in the whole constraint matrix during current run
MAXM	Maximum number of constraints encountered during current run
MAXN	Maximum number of variables encountered during current run
PICK	Size of candidate list used for multiple pricing
PRINT	Specifies the level of printing desired: 0 means error messages only; 1 means termination condition messages (optimal solution, unbounded, infeasible); 2 means print the objective function value after every basis refactorization; 3 means log information at every iteration
	Dimensioned Variables
Real Arrays	
B	MAXM
BASCB	MAXM
BASLB	MAXM
BASUB	MAXM
BETAR	MAXM (needed for dual simplex method)
CANDA	COLMAX,PICK
CANDCJ	PICK

Table C7-6 (contd.)

Variable	Description
COLA/VAL	COLMAX
MEMORY	LENMY
UZERO	MAXM
XBZERO	MAXM
YQ	MAXM
Integer Arrays	
MAPA	20
MAPI	20
BASIS	MAXM
CAND	PICK
CANDI	COLMAX,PICK
CANDL	PICK
COLI/IRO	COLMAX
ROWTYP	MAXM
STATUS	MAXN

REFERENCES

1. James J. Stukel. **"Advanced Utility Simulation Model, Analytical Documentation, State Level Model (Version 1.0)."** U.S. Environmental Protection Agency. EPA-600/8-88-071a. January 1989.

2. R.E. Marsten. **"The Design of the XMP Linear Programming Library."** ACM Transactions on Mathematical Software. Vol. 7, No. 4. Pages 481-497. December 1981.

3. Caroline J. Badger and Howard Ojalvo. **"Advanced Utility Simulation Model, Documentation of System Design, State Level Model (Version 1.0)."** U.S. Environmental Protection Agency. EPA-600/8-88-071c (NTIS PB89-101208). August 1988.

C8. THE FINANCIAL MODULE

by

Mark Younger and Kathleen Cole

Universities Research Group on Energy
Cornell University

8.1 Overview

The two main functions of the financial module of the Advanced Utility Simulation Model (AUSM) are to calculate the required revenue of the utilities and to formulate the financial statement of the utilities. The revenue requirement is based on information about utility asset accounts, which are derived in the financial module, and maintenance, fuel and purchased power cost information passed from other parts of AUSM.

Each state utilizes both national-level and state-specific data. The national information specifies depreciation schedules, investment tax credit rates and the corporate income tax rate. The state-level information specifies the level of asset and liability accounts for the utilities in 1980, state tax rates (corporate income tax and others) and information about the regulatory environment of that state.

In the first year of the simulation, the financial module sets up asset and liability accounts as they were in 1980. For the variables related directly to the electric utility plant this requires depreciation of the gross plant and estimation of plant age to initialize the various asset, depreciation and deferred tax accounts for every year in the simulation. The investment tax credit and debt accounts are also initialized for all years. All other asset and liability accounts are set only for the first year.

After the accounts are initially set in the first year, and for each subsequent year, the financial module performs the following tasks:

1. Keeps track of total direct investment and direct investment plus AFUDC charges on all assets under construction.

2. Sets up depreciation schedules for each asset that has been constructed and adds it to the gross asset accounts.

3. Calculates the required revenues for the utilities

4. Calculates the percentage of total revenue requirement accounted for by different fuels, by maintenance expense, by purchased power cost, and by the return to capital

5. Calculates the financial needs of the utilities and either issues new debt and equity if the financial needs are positive, or retires additional debt and equity if the needs are negative

6. Calculates the interest coverage and profitability ratios for the year

7. Prepares the financial statement accounts for the year.

Additional discussion of the financial module appears in Chapter 3 of the analytical documentation of the AUSM [1].

Figure C8-1 is a schematic representation of subroutine FINANC of the financial module. R602 prints the financial statements in the final year of the simulation.

8.2 Module Operation

The following sections describe the workings of the financial subroutines sequentially and in detail. These subroutines are FINANC and its associated subroutines DEPREC and ROUND, which are parts of AUSM, and R601 and R602, which are parts of the report writer AUSMR. The analytical documentation [1], provides the rationales and many of the algorithms for these operations. It should be read first and consulted while reading this section.

8.2.1 FINANC Subroutine

8.2.1.1 Initialize Base-Year Accounts

In the first simulation year, the model receives exogenous financial data and the financial scenario variables.

Figure C8–1
SCHEMATIC REPRESENTATION OF THE FINANCIAL MODULE

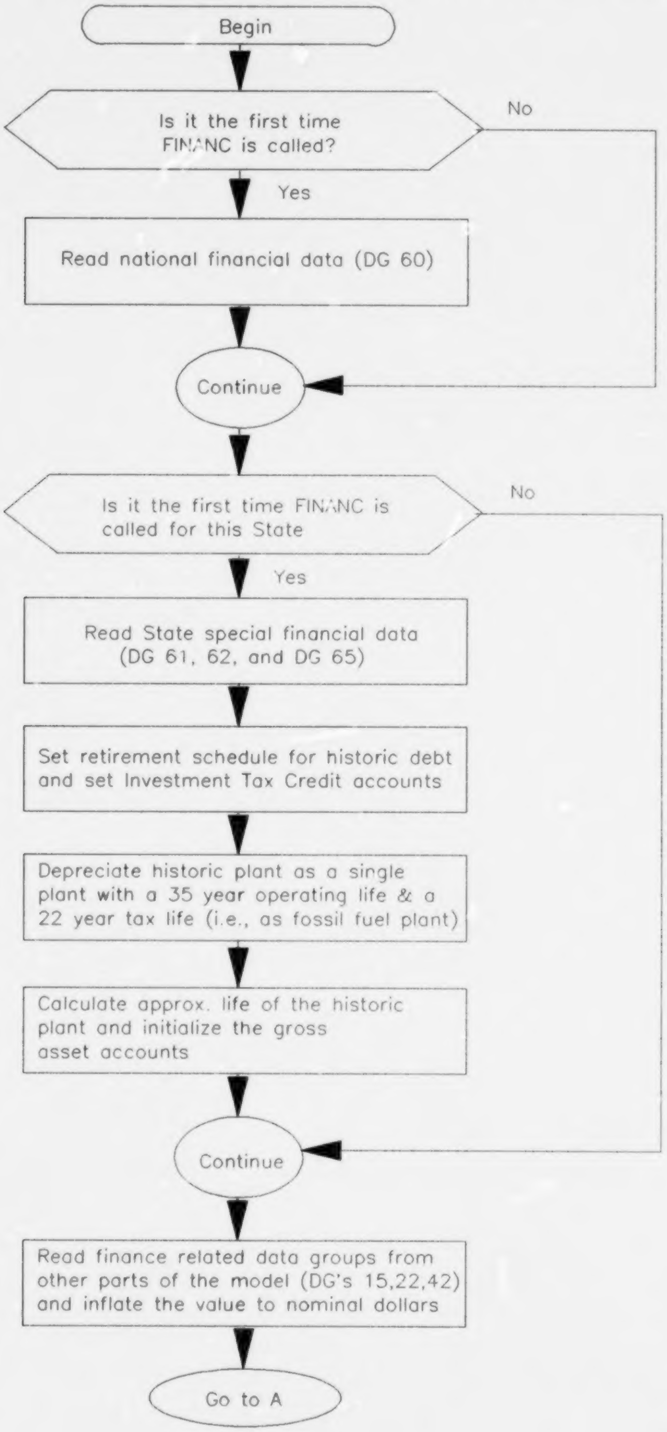

Begin
Is it the first time FINANC is called?
No
Yes
Read national financial data (DG 60)
Continue
Is it the first time FINANC is called for this State
No
Yes
Read State special financial data (DG 61, 62, and DG 65)
Set retirement schedule for historic debt and set Investment Tax Credit accounts
Depreciate historic plant as a single plant with a 35 year operating life & a 22 year tax life (i.e., as fossil fuel plant)
Calculate approx. life of the historic plant and initialize the gross asset accounts
Continue
Read finance related data groups from other parts of the model (DG's 15,22,42) and inflate the value to nominal dollars
Go to A

Figure C8-1 (contd.)

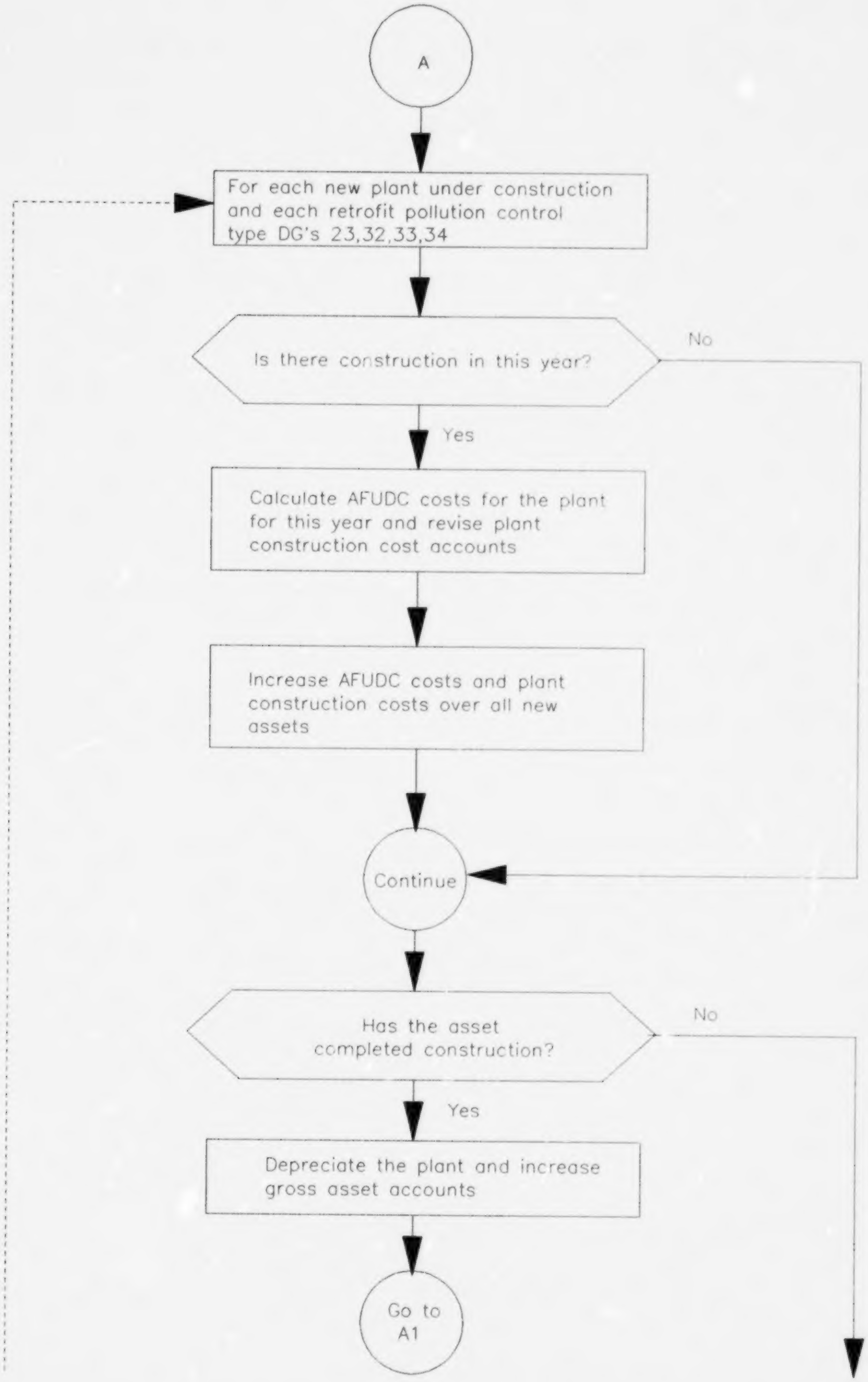

A
For each new plant under construction and each retrofit pollution control type DG's 23,32,33,34
Is there construction in this year?
No
Yes
Calculate AFUDC costs for the plant for this year and revise plant construction cost accounts
Increase AFUDC costs and plant construction costs over all new assets
Continue
Has the asset completed construction?
No
Yes
Depreciate the plant and increase gross asset accounts
Go to A1

Figure C8-1 (contd.)

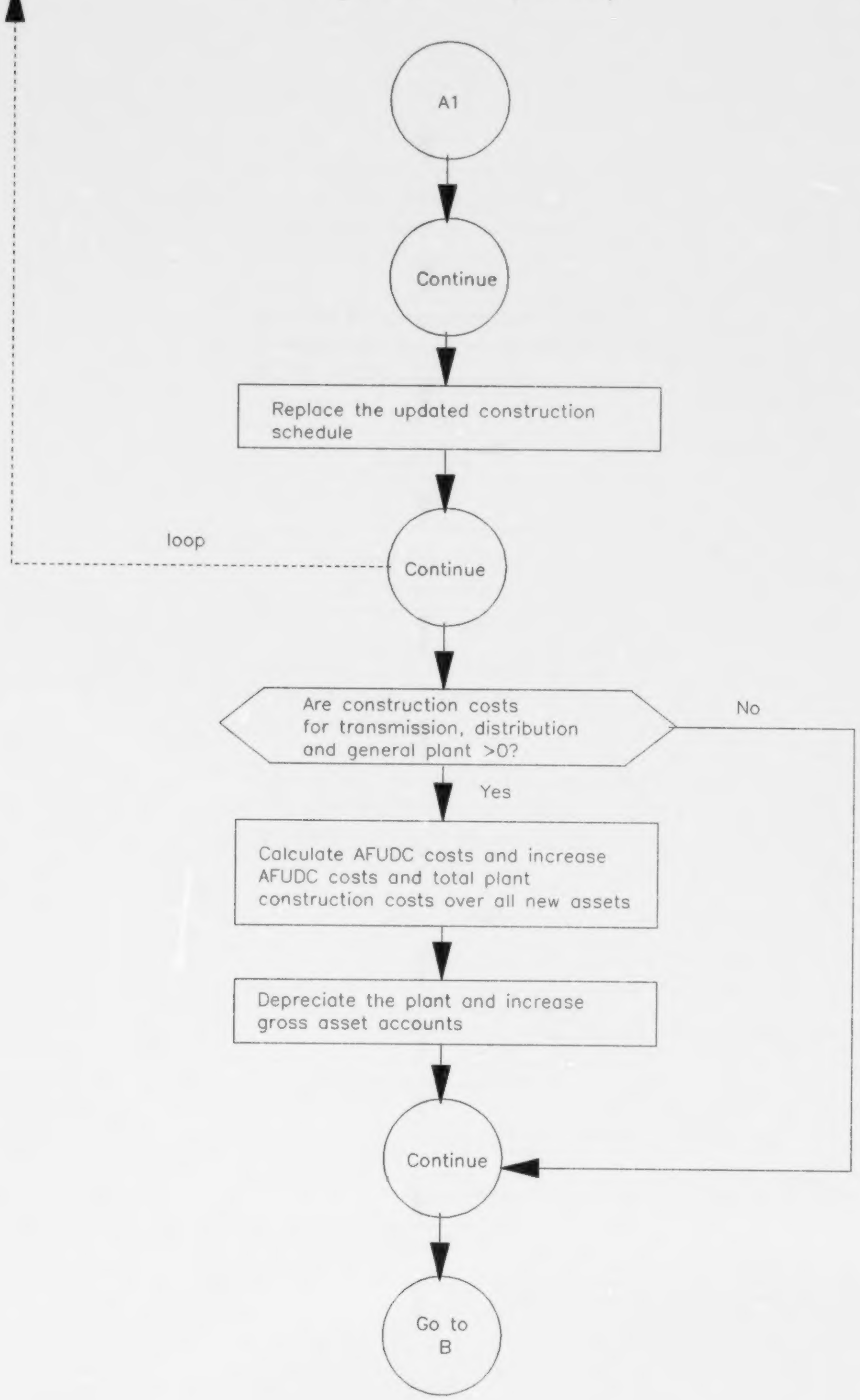

A1
Continue
Replace the updated construction schedule
loop
Continue
Are construction costs for transmission, distribution and general plant >0?
No
Yes
Calculate AFUDC costs and increase AFUDC costs and total plant construction costs over all new assets
Depreciate the plant and increase gross asset accounts
Continue
Go to B

Figure C8–1 (contd.)

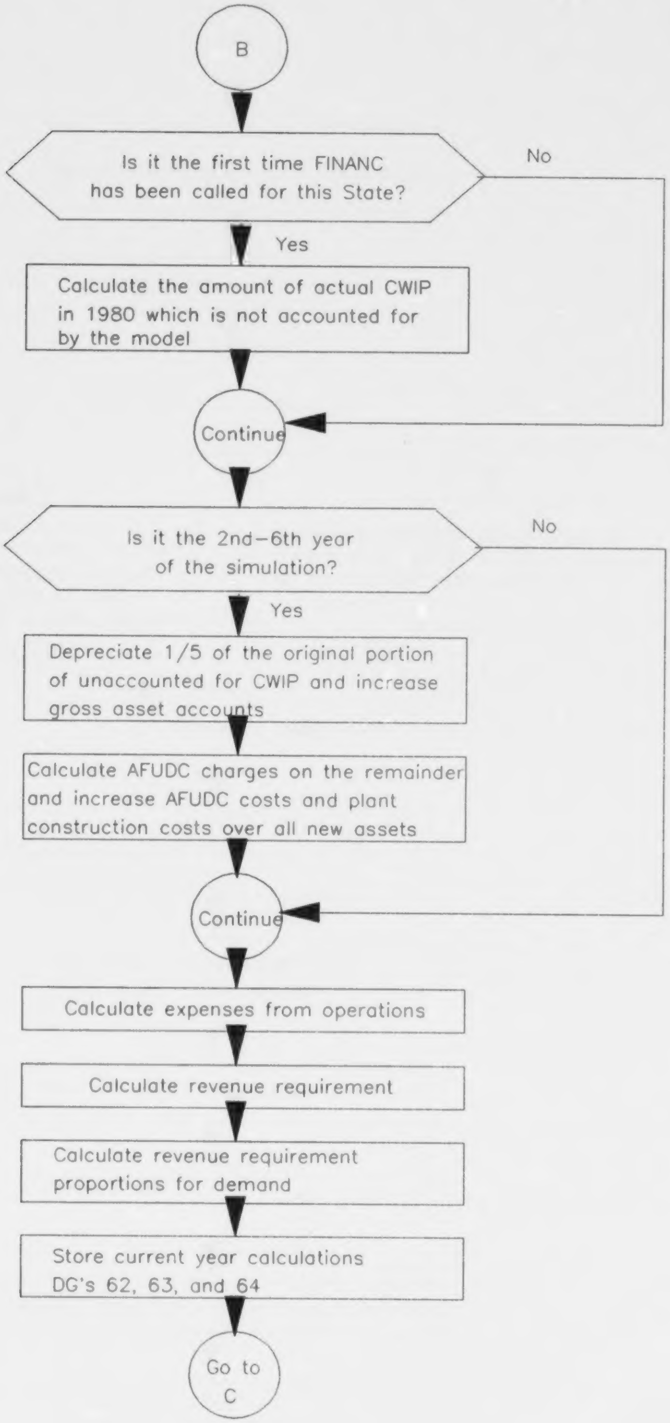
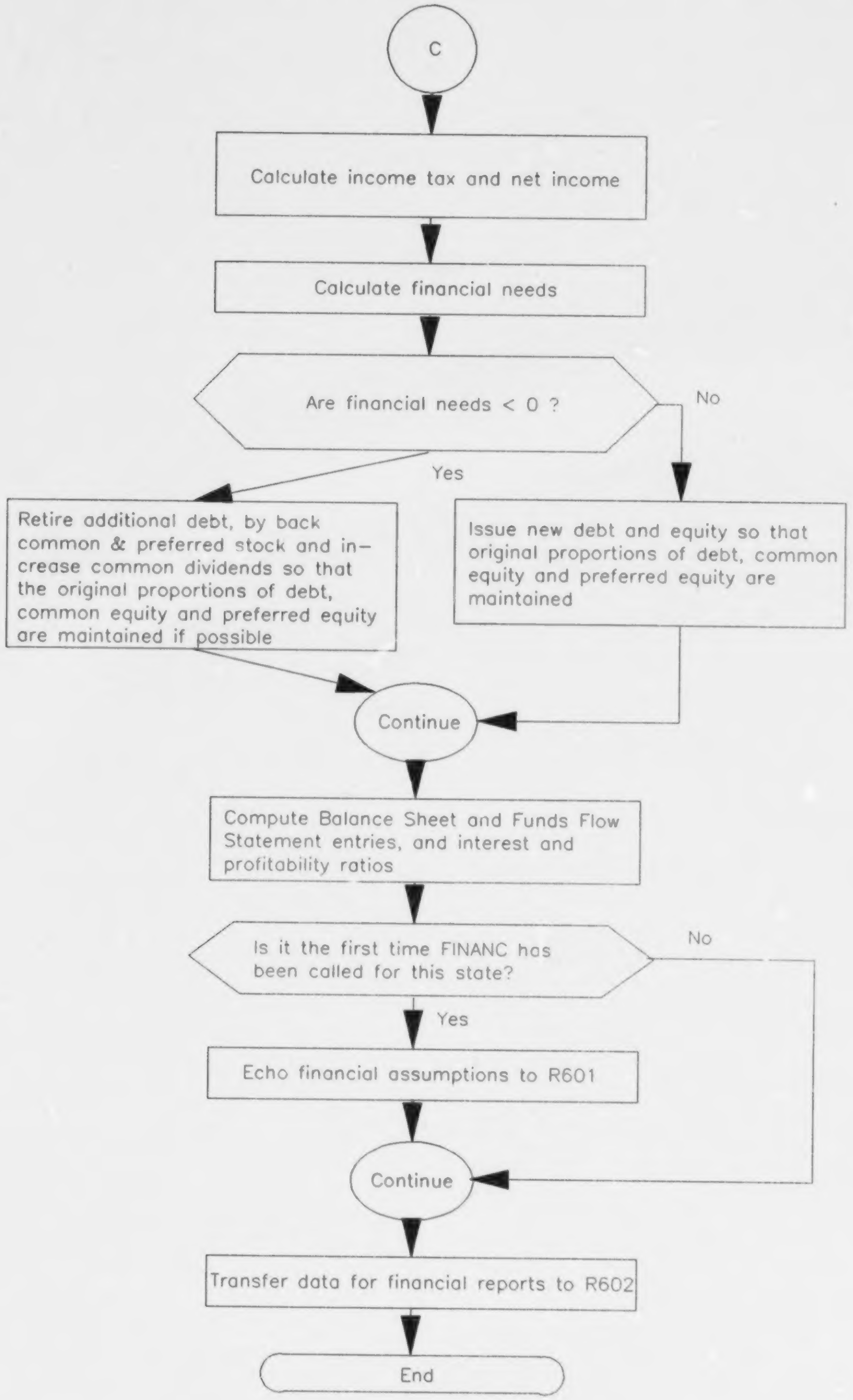

B
Is it the first time FINANC has been called for this State?
No
Yes
Calculate the amount of actual CWIP in 1980 which is not accounted for by the model
Continue
Is it the 2nd–6th year of the simulation?
No
Yes
Depreciate 1/5 of the original portion of unaccounted for CWIP and increase gross asset accounts
Calculate AFUDC charges on the remainder and increase AFUDC costs and plant construction costs over all new assets
Continue
Calculate expenses from operations
Calculate revenue requirement
Calculate revenue requirement proportions for demand
Store current year calculations DG's 62, 63, and 64
Go to C

Figure C8–1 (contd.)


C
Calculate income tax and net income
Calculate financial needs
Are financial needs < 0 ?
No
Yes
Retire additional debt, by back common & preferred stock and increase common dividends so that the original proportions of debt, common equity and preferred equity are maintained if possible
Issue new debt and equity so that original proportions of debt, common equity and preferred equity are maintained
Continue
Compute Balance Sheet and Funds Flow Statement entries, and interest and profitability ratios
Is it the first time FINANC has been called for this state?
No
Yes
Echo financial assumptions to R601
Continue
Transfer data for financial reports to R602
End

The national data are used from data group 60[1] and stored in the common block /FINNAT/. These data are read only in the first iteration of a run, signaled by the binary variable FIRST. FIRST is initialized with the value "true", and, with this value, the code for reading data group 60 is accessed. Once it is read, FIRST is assigned the value "false". Thereafter, this part of the code is skipped.

At this point, the number of the current and the next iteration are set (IYR and NXTYR), and the inflation factor is determined from the general inflation rate RINF as follows:

$$RINFF = (1 + RINF)**(IYR - 1). \qquad \text{[Eq 1]}$$

If the iteration is the first for a particular state, the module then reads state-level exogenous data from data groups 61, 62, and 65. Access to this part of the code is controlled by checking ISTATE, the code for the state then being processed, with LSTATE. In the first iteration of a simulation, LSTATE equals zero. Just after these data groups are read, LSTATE is set equal to ISTATE. If ISTATE equals LSTATE, then this section is skipped. The values from data group 61 are stored in the common block /FINSTA/. /FINNAT/ and /FINSTA/ hold their values for the duration of the simulation. The base year asset and liability values come from data groups 62 and 65. They are used to calculate base asset and liability accounts for the duration of the simulation; these accounts are stored in blank common blocks. The initial values are stored in /FINSTA/ with data group 61.

Here, the value of base-year nonelectric assets (OASS) is computed. To maintain consistency between the financial statements and the revenue requirement computed by the model on the basis of electric assets only, the data have been adjusted so that $OASS = 0$.[2] The combined effective state and federal corporate income tax rate ETXR is computed. Finally, the value of TDCWIP, which ultimately will equal the amount of base-year cwip remaining after known construction projects have been deducted, is initialized with the exogenous value of base-year cwip, CWPE.

---

[1] All data groups are described in the documentation of AUSM system design [2].

[2] The way in which the data are adjusted is described in Section 3.4.3.4 of the data documentation [3].

Reproduced from best available copy.

8.2.1.2 Calculate Base Simulation Period Accounts

If ISTATE does not equal ISTATE (i.e., if it is the first simulation year for a state), the model then constructs simulation-period accounts from certain of the base-year variables.

First, a debt retirement schedule is approximated for base-year outstanding debt and the base-year debt retirement value (DRET) is exogenously supplied. To avoid the large data collection and processing problem of deriving a retirement schedule from actual utility bond issues and maturities, base-year debt is paid off like a mortgage. The amortization factor is

$$AMF = (RINT*(1 + RINT)**20)/((1 + RINT)**20 - 1). \qquad [Eq\ 2]$$

The variable H, initialized to 1.0, defines the fraction of debt still outstanding, so that

$$H_t = H_{t-1} *(1 + RINT) - AMF. \qquad [Eq\ 3]$$

where RINT is the interest rate, and after the first year,

$$DRETIR_t = (OLDT_1 + NWDT_1)*(H_{t-1} - H_t). \qquad [Eq\ 4]$$

DRETIR is the amount of debt retired, and $OLDT_1$ and $NWDT_1$ are base-year values of previous and new debt.

The model then sets up the simulation period accounts for the base-year values of accumulated investment tax credit (itc). There are two accounts: one for book purposes, which appears on the balance sheet, and one used by the regulatory commission to reduce the value of the rate base. Both are amortized over time. The model first determines the numerator (FRITC) of the fraction of accumulated itc that will be deducted from the rate base. This depends on the value of the policy flag, NORMFT:

NORMFT = 1 signals full normalization of tax savings (FRITC = ZITCR(YR))

NORMFT = 2 signals flow through of tax savings (FRITC = 0.0)

NORMFT = 3 signals partial normalization of tax savings (FRITC = 0.08).

The implication of these policies for the algorithm are discussed in detail in section 3.2.1.9 of the analytical documentation [1]. After this adjustment to total base-year accumulated itc (TOTTC) to give the value for regulatory purposes (REGTC), the two accounts ACTCT and ACITC are amortized over time as follows:

$$ACITC_t = REGTC - ((REGTC/LITC) * (t - 1)) \quad \text{[Eq 5]}$$

$$ACTCT_t = TOTTC - (TOTTC/LITC) * (t - 1)). \quad \text{[Eq 6]}$$

LITC is the assumed amortization period. (TOTTC/LITC) is stored in the variable TCTKN each year: TCTKN is the value of the tax credit reported in the income statement.

Now the program approximates the depreciation accounts for historical plant. Sections 3.2.1.3, 3.2.1.4, and 3.2.1.5 of the analytical documentation explain the assumptions used in these calculations. Treating all assets as a single plant, its approximate age is calculated as

$$IAGEBK = ((1 - (NETPLE/GRSPE)) * LIFN + 0.5). \quad \text{[Eq 7]}$$

This value contributes to the calculation of HADF, the fraction of historical plant assumed to use accelerated depreciation for tax purposes. At present, HADF is computed outside the model and entered as data; Section 3.4.3.4 of the data documentation [3] provides a suggested program for updating it.

The values for yearly and accumulated depreciation and deferred tax accounts are computed by the subroutine DEPREC, described in detail in Section 8.2.2. FINANC passes to DEPREC values for book or operating life (LIFN), tax life (LIFT), construction costs including afudc (RBS), afudc (AFC), a code for type of asset (ASSTYP) which is explained in section 8.2.1.4 of this documentation, the effective corporate income tax rate (ETXR), the policy variable for regulatory treatment of tax savings (NORMFT), the maximum allowed accelerated depreciation rate (DBLR), the reduction in tax basis for the itc that is required after 1982 (TCADJ), HADF, the current simulation year, e.g., 1980 (IYEAR), and the tax depreciation schedule appropriate under Accelerated Cost Recovery System (ACRS) for the type of asset (DPRATE). FINANC receives arrays from DEPREC for accumulated straight-line depreciation of gross plant and of the tax basis (ACDSL1 and ACDSL3), the yearly value of tax depreciation assumed by the state regulatory commission (RGDP), the accumulated deferred tax used to adjust the rate base (ACRGDF), yearly straight-line depreciation of gross plant (DSL1), actual tax depreciation (TXDP), and accumulated and yearly deferred taxes for book purposes (ACBKDF and BKDF).

In this historical plant section, FINANC begins with the values in these arrays that correspond to the plant's assumed age, IAGEBK, and uses subsequent values to initialize its aggregate accounts for these variables: ACDSL1 values are added to ADPRBE, ACDSL3 values to ADPTBE, and so forth. At the same time, other aggregate accounts are initialized with the historic plant values: GRSSPE with GRSPE, and TBASE with GRSPE times the percentage assumed to be direct construction costs.

8.2.1.3 Retrieve Working Financial Arrays and Operations Data

The next section, which is skipped in the first simulation year for a state, obtains from data group 64 the previous year's values for the aggregate account arrays just discussed.

Next, the model calculates the current year's embedded interest rate on new debt as follows.

$$RINT = (OLDT * RINT + NWDT * RINTM)/OLDLTD$$

where OLDT, NWDT, and OLDLTD are old, new, and total outstanding new debt and RINTM is the user-specified desired interest rate. RINTM is accessed via GETSCN(55). If the utilities located within the current state are primarily publicly owned (i.e., if ISTATE is Tennessee or Nebraska), this step is bypassed and the interest rate on new debt remains constant at the 1980 rate.

Then the model calculates the current year's embedded rate of return on preferred equity according to the formula:

$$\mathrm{PRET} = (\mathrm{VOLDPEQ} * \mathrm{PRET} + \mathrm{NWPEQ} * \mathrm{PRETM})/\mathrm{OLDPEQ}$$

where VOLDPEQ, NWPEQ, and OLDPEQ are old, new, and total outstanding preferred equity and PRETM is the user-specified desired rate of return. PRETM is accessed via GETSCN(56).

Following this, in each simulation year, the program obtains data on purchased power costs, total kilowatt hour sales and operating revenues from data group 15; on transmission, distribution, and general plant construction expenses from data group 22; and on fuel and operating costs from data group 42. It then adjusts the data group 15 and 42 monetary values to nominal dollars, using RINFF.

8.2.1.1 Obtain and Process Construction Expenditures for New Generating Plant and Pollution Equipment

The model now calculates the weighted average debt and equity rates, RADCD and RADCE, that are used in the computation of afudc. These are discussed in Section 3.2.1.2.1 of the analytical documentation. The policy flag variable IRATE signals whether a state uses a before-tax value for RADCD (IRATE = 1) or an after-tax value (IRATE = 0).

The program then retrieves data on construction costs from data groups 23 (new plant), 32 (retrofit SO_2 control devices), 33 (retrofit NO_x devices), and 34 (retrofit TSP devices). The code reads and processes one data group at a time, in a loop. Within data group 23, the program first reads the number of plants under construction (NSCHED) and does the construction loop NSCHED times before going through it for the other data groups. Before entering the loop, the program initializes the aggregate construction accounts for the year to zero.

From each data group, the program obtains values for the year construction begins (C), the year the asset comes on-line (S), the direct construction costs incurred so far (VEST), construction work in progress to date (construction costs plus afudc) (CWP), the investment tax credit earned by the asset so far (TOTITC), and values from which that year's direct construction costs (CONEXP) are computed. For generating facilities, CONEXP equals the sum of total capital costs for generating plant and any of the three types of pollution control equipment multiplied by the fraction spent this year. Each of the retrofit categories is processed separately and for them, CONEXP equals simply the total capital cost for that device times the fraction spent that year. A final data item received for generating facilities is the code for type of prime mover. It determines the asset type for depreciation purposes (ASSTYP) by means of IBRIDGE, as follows:

	ASSTYP	=	*IBRIDGE (I)*	where *I = Prime Mover Type*
Fossil steam		1	1	1 Fossil steam
Combustion turbine		2	2	2 Geothermal
Hydro		3	3	3 Conventional hydro

Nuclear steam	4	3	4	Pumped storage hydro
Transmission	5	4	5	Nuclear steam
Distribution	6	2	6	Internal combustion
Retrofit pollution control	7	2	7	Combined cycle
		2	8	Combustion turbine
		2	9	Exotic

Data from groups 32, 33, and 34 are assigned an ASSTYP of 7 directly. Transmission, distribution, and general plant construction costs are assigned an ASSTYP of 6 when they are processed in a later section of code.

The program puts CONEXP in nominal dollars and computes the investment tax credit earned by the asset in that year:

$$ZITC = CONEXP * ELIG(ASSTYP) * ZITCR(IYR) \qquad \text{[Eq 8]}$$

where ELIG is the fraction of the costs eligible for the credit and ZITCR is the tax credit rate in that year. See Section 3.2.1.6 of the analytical documentation for a discussion of the credit and the values of these variables.

Next, the program calculates the year's afudc and augments the CWP, VEST, and TOTITC accounts for the asset. The afudc concept and the calculations are described in detail in Section 3.2.1.2 of the analytical documentation. Two policy flag variables come into play here, and their effect on the algorithms is discussed in Section 3.2.1.2 of the analytical documentation. ICWIP equals 1 if a state allows 100 percent of cwip in the rate base and 0 if it does not. A value of 1 causes the afudc calculations to be skipped entirely. ICUM determines whether afudc is computed cumulatively, that is, on the basis of previously earned afudc; it equals 1 if it is computed cumulatively, 0 if not.

These asset-level values, AFDCD, AFDCE, CWP, VEST, CONEXP, and ZITC, then augment that year's aggregate values of AFUDCD, AFUDCE, CWIPE, CWPP, CWPE, ADDP, ADDE, and ITC. In addition, if ICWIP = 1, CWP is added to the year's gross rate base value, GRSSRB.

Reproduced from
best available copy.

The model then checks to see if the current simulation year equals the year the plant comes on-line (the year on-line is coextensive with the last construction year). If less than this value, it skips the next section of code, places the updated values of CWP, VEST, and TOTITC in the appropriate data group, and either goes through the construction loop again or exits.

If the asset comes on-line that year, the model sets HADF equal to 1.0, sets TCADJ equal to 0.5 times TOTITC, assigns the appropriate depreciation schedule to DPRATE, and calls the subroutine DEPREC. The arguments passed are outlined in Section 3.2.1.2, and the subroutine is described in Section 8.2.2. The values for the asset's depreciation and deferred tax accounts are then added to the aggregate accounts for these variables, as with historical plant. With new plant, however, the first-year values of the arrays from DEPREC are added to the aggregate account values for the next simulation year. Also in this section, the values for gross electric plant, gross rate base, and the tax basis (GRSSPE, GRSSRB and TBASE) are increased by CWP and VEST. In addition, the book and regulatory accumulated tax credit accounts are augmented by TOTITC and by the fraction of TOTITC dictated by NORMFT. These two accounts are then amortized over the simulation period. TCTKN is augmented by the yearly amortization of TOTITC. The program then updates cumulative values in the appropriate data group and either redoes the loop for a different asset or exits.

8.2.1.5 Process Transmission, Distribution, and General Plant Expenditures and Historical Cwip Not Accounted for by the Base Year's Plant-Level Data

The next section of code is a loop that performs both these functions. When L = 1, it processes transmission, distribution, and general plant construction costs (if their sum equals 0, it goes to the end of the loop). It calculates afudc and tax credit accounts, and since it is assumed to have a one-year construction period, it skips code related to the loop's second function and immediately calls DEPREC to compute the depreciation and deferred tax accounts. The calculations of the asset-level values and the augmenting of aggregate accounts are carried out exactly as those for other new construction described in the preceding section. There are no values stored, however, since the construction period is only one year.

When L = 2, and if the simulation year (IYR) = 1, the program skips the code that calculates afudc for transmission, distribution and general plant. It goes to a section that computes the value of base year construction work in progress (cwip) not accounted for by the specific plant data already processed in the first simulation year:

$$TDCWIP = TDCWIP - CWIPE. \qquad \text{[Eq 9]}$$

(Recall that TDCWIP has been initialized with the exogenous value of CWPE.) Also in IYR = 1, TDVEST is initialized as (TDCWIP * TBSPC) and TDCWIP is divided by (1 + RADCD + RADCE) to remove the current year's afudc. Also, the base year value of ADDE is overridden by the exogenous ADDNET, and ZITC is initialized to zero. Then, in IYR = 1, the program skips to a section near the end of the loop, where it computes afudc based on the value of TDCWIP (or TDVEST if noncumulative), but otherwise follows the algorithms described in Section 3.2.1.2.1 of the analytical documentation.

As discussed in Section 3.2.1.2.2 of the analytical documentation, TDCWIP is treated as a five-unit fossil fuel steam generating facility (thus ASSTYP = 1) which is brought on-line one unit at a time over the second through sixth simulation years.

If L = 2 and IYR is greater than 6, the program exits the loop, but if L = 2 and IYR = 2 through 5, the model immediately skips to a section that computes the amount to be brought on-line that year:

$$CWP = TDCWIP/(7 - IYR) \qquad \text{[Eq 10]}$$

$$VEST = TDVEST/(7 - IYR) \qquad \text{[Eq 11]}$$

It then computes new balances for TDCWIP and TDVEST by deducting CWP and VEST from the old values. The amount of investment tax credit attributable to this unit is

$$TOTITC = VEST * ELIG(ASSTYP) * ZITCR(YR) \qquad \text{[Eq 12]}$$

and TCADJ equals half of that value. Since the asset is assumed to use accelerated tax depreciation, HADF = 1.0.

The program then calls DEPREC to compute accounts for CWP and VEST, and these values are added into the aggregate accounts as for new plants, discussed in Section 3.2.1.4. Also, as described in Section 3.2.1.4, the mode augments the aggregate accounts for gross plant, tax base, and accumulated tax credits.

Afudc and related values are then calculated on the current balance of TDCWIP, completing the loop.

8.2.1.6 Calculate Required Revenue

The model now computes values for property tax, administrative expenses, and Social Security and "other" taxes, and sums these with fuel, operating, and purchased power costs.

After computing the adjusted rate base (ADJRBS), as discussed in Sections 3.2.1.4 and 3.2.1.9 of the analytical documentation, the program calculates revenue requirement as described in Section 3.2.1 of that source.

8.2.1.7 Calculate Revenue Requirement Proportions for the Demand Module

The model then calculates certain costs as percentages of revenue requirement and stores these values in data group 63 for retrieval by the demand module.

8.2.1.8 Compute Values for Financial Statements and Determine Financial Needs

The module then begins to compute values for the financial statements and to determine the utilities' financial needs (except in the first year, when financial needs are exogenous).

As a first step, the program calculates the year's interest expense, the federal and state corporate income tax expense, and the items comprising the income statement. The rationale for the interest expense calculation and a detailed discussion of the equations for income taxes and net income are presented in the analytical documentation, Section 3.2.2.1.

Having computed net income, the model calculates the year's dividend payments and the end-of-year balance of the retained earnings account.

Next, the accounts for current and other liabilities and for accounts receivable (LIACAO and ACCTR) are inflated to nominal dollars. They are otherwise constant throughout the simulation period. The utilities' financial needs for the year are then calculated. If they are negative, the program retires long-term debt, buys back preferred and common stock, and increases common dividends, as described in the analytical documentation, Section 3.2.2.1. That section also discusses in detail the equations that apportion positive financial needs among long term debt, and common and preferred stock issues. However, the equations that retire additional debt require further discussion. When financial needs are negative, the desired level of debt, DDEBT, is calculated. Additional debt to be retired is, then,

$$DEBTCH_t = LTDTOT_{t-1} - DRETIR_t - DDEBT_t \qquad [\text{Eq } 13]$$

where $LTDTOT_{t-1}$ is the previous year's total long-term debt and $DRETIR_t$ is the debt retirements already scheduled. Then, after the equity accounts have been adjusted to their desired levels, a short loop searches through the future values of DRETIR and transfers them to SUMRT until the amount DEBTCH has been reduced to zero or until there is no debt remaining to be retired. In either case,

$$DRETIR_t = DRETIR_t + SUMRT. \qquad [\text{Eq } 14]$$

In the latter case, the account for cash balances is increased by the amount of DEBTCH remaining:

$$CASH_t = CASH_t + DEBTCH. \qquad [\text{Eq } 15]$$

CASH is initialized to zero each year, and later is added to ACCTR to give the balance sheet accounts for current and other assets, ASSCAO.

After computing accounts for prior and total long-term debt and equity, the model calculates the balance sheet items (described in the analytical documentation, Section 3.2.2.2), the funds flow accounts (Section 3.2.2.3) and the interest coverage and profitability measures (Section 3.2.2.4).

8.2.1.9 Store Values of Financial Variables

Finally, the rates of return, TDCWIP, and TDVEST are stored in data group 62, working arrays for the aggregate accounts are stored in data group 65, and a large number of variables needed by the financial statement report writer R602 are written to unit 10.

8.2.2 DEPREC Subroutine

This subroutine has essentially three parts: one that computes types of depreciation accounts, e.g., straight line, accelerated; one that assigns these values to functional accounts, e.g., for tax, book, or regulatory purposes; and one that stores these accounts in arrays to be passed back to FINANC. The choices among the complex tax and regulatory policies concerning depreciation are made within this subroutine.

The effects of the policy choices are returned to FINANC.

DEPREC receives values from FINANC for an asset's operating life (LIFN), tax life (LIFT), construction cost including afudc (RBS), afudc earned (AFC), asset type code (ASSTYP), the effective corporate income tax rate (ETXR), the policy flag for the regulatory treatment of tax savings (NORMFT), the maximum allowed accelerated depreciation rate (DBLR), the reduction in tax basis for the itc that is required after 1982 (TCADJ), the fraction of the asset assumed to use accelerated tax depreciation (HADF), the date of the current simulation year (IYEAR), and the appropriate ACRS depreciation schedule (DPRATE). DEPREC returns arrays for accumulated straight-line depreciation of gross plant and of the tax basis (ACDSL1 and ACDSL3), the yearly value of tax depreciation assumed by the state regulatory commission (RGDP), the accumulated deferred tax used to adjust the rate base (ACRGDF), yearly straight-line depreciation of gross plant (DSL1), actual yearly tax depreciation (TXDP), and accumulated and yearly deferred taxes for book purposes (ACBKDF and BKDF).

Certain sections of the analytical documentation provide background, rationales, and key equations for the calculations of DEPREC. Section 3.2.1.3 discusses the depreciation bases; 3.2.1.5 describes the tax depreciation options and the variable HADF; 3.2.1.7 presents the depreciation provision for retrofit pollution control equipment; and 3.2.1.9 explains the various regulatory policies regarding tax depreciation and their implications for algorithms. The following discussion of DEPREC's operations presumes familiarity with those sections.

8.2.2.1 Initialize Variables and Calculate Various Types of Depreciation Accounts for the Asset

DEPREC first creates integer values for the asset lives, initializes the arrays and cumulative variables to zero, and computes the tax basis:

$$CCO = RBS - AFC, \textit{ before } 1983 \qquad \text{[Eq 16]}$$

$$CCO = RBS - AFC - TCADJ, \text{ 1983 and } \textit{later}. \qquad \text{[Eq 17]}$$

It also assigns an initial value of 1.0 to the variables (DB1 and DB2) that represent the fraction of the tax basis remaining to be depreciated when the pre-1981 system is used. In addition it calls the subroutine

ROUND, which calculates the year in which it becomes advantageous to switch from declining balance to straight-line depreciation. ROUND can make this computation for any combination of declining balance rates (DBR) and asset lives (e.g., LIFT or LIFN). DEPREC calls it twice with the on-line year's maximum DBR, once using LIFT and once using LIFN. As explained in the analytical documentation, Section 3.2.1.9, accelerated depreciation accounts computed with the tax life and with the operating life are needed for the partial normalization policy.

The program then enters a loop that encompasses the three key sections of the subroutine. First, it simply computes types of depreciation accounts.

Any accounts for computing tax depreciation or deferred taxes must reflect the IRS convention that only half of a full year's tax depreciation may be claimed as a deduction in the first year the asset is in use. Thus a new tax basis variable, KKO, is defined, which equals 0.5 times CCO in the first year and CCO in subsequent years. In the final depreciation year for straight-line accounts, KKO is multiplied by 1.5 so that the asset will be fully depreciated. When the accelerated depreciation accounts switch from a declining balance to a straight line or sum of the years' digits method, the remaining basis is automatically exhausted without this adjustment.

The program then calculates the following accounts. Straight-line depreciation of gross plant (construction costs including afudc) over the operating life is DS1 and is straightforward. DS2, straight-line depreciation of the tax basis over the tax life, reflects the half-year convention adjustments just discussed, as does DS3, straight-line depreciation of the tax basis over the operating life.

The next accounts are for accelerated depreciation under old and new versions of the tax code. First, the program computes accelerated depreciation under the old version that applies to assets on-line as of 1980 or earlier. At present, this code is skipped if IYEAR is greater than 1980. This should be changed if the model is to use a base year greater than 1980, since this version will apply to virtually all historical plant and should be used when historical plant is processed even though IYEAR will always be greater than 1980. It will probably be necessary to flag historical plant specifically. DA1, then, is accelerated depreciation of the tax basis over the tax life. Under the old law, it is the declining balance method with a switch to straight line, using DB1 to keep track of the declining basis (it is recalculated near the end of the loop). Under the new law, DPRATE is simply applied to the full basis. Section 3.2.1.5 of the analytical documentation describes these methods. DA2 uses the old tax law method, with DB2 keeping track of the basis, but it is calculated over the operating life rather than the tax life. It is used when the partial normalization option is in effect. Then, but only if ASSTYP = 7 (retrofit pollution control equipment), the program calculates DSPOL, the special variety of tax depreciation available to these assets. The analytical documentation, Section 3.2.1.7, describes this provision in detail.

8.2.2.2 Create Functional Depreciation and Deferred Tax Accounts

DEPREC then uses these values to create functional accounts for tax, regulatory and book purposes. The regulatory policies, signaled by NORMFT and discussed in Section 3.2.1.9 of the analytical documentation, determine many of these assignments.

First, a value is assigned to actual tax depreciation, TXD. If ASSTYP = 7, TXD = DSPOL. If not, TXD is a weighted average of DA1 and DS3, where HADF is the fraction of accelerated depreciation used. In fact, HADF will equal 1.0 for all new plant, and in some states equals 1.0 even for historical plant (see Section 3.2.1.5 of the analytical documentation for a discussion of HADF).

DEPREC then determines RGDP, the value used for tax depreciation in the regulatory tax allowance equation. If

NORMFT = 1 (full normalization) RGDP = DS3, straight-line depreciation of the tax basis over the operating life

NORMFT = 2 (flow through) RGDP = TXD if IYEAR is less than 1980; RGDP = DS3 if IYEAR is greater than 1980 because the new tax depreciation provisions may be used only if they are fully normalized

NORMFT = 3 (partial normalization) RGDP = DA2, accelerated depreciation over the operating life, if IYEAR is less then 1980; as with NORMFT = 2, RGDP = DS3 if IYEAR is greater than 1980

Next, the program computes deferred tax accounts. For book purposes,

$$BKDEF = (TXD - DS3) * ETXR. \qquad [\text{Eq } 18]$$

Deferred tax for regulatory purposes, RGDF, depends on the policy signaled by NORMFT, and can be summarized as

$$RDGF = (TXD - RGD) * ETXR, \qquad [\text{Eq } 19]$$

where RGDP depends on NORMFT and IYEAR as outlined above.

DEPREC then calculates the accumulated depreciation and deferred tax accounts that are needed by FINANC: accumulated straight-line depreciation of gross plant (ADS1), accumulated straight-line depreciation of the tax basis (ADS3), and accumulated regulatory and book deferred taxes (ARGDF and ABKDF).

Finally, it adjusts the values (DB1 and DB2) that keep track of the accelerated depreciation basis.

8.2.2.3 Assign Values to Arrays

The final section of the subroutine assigns to arrays the values needed by FINANC.

8.2.3 The Financial Report Writing Subroutines

The first of these subroutines, R601, merely prints a table of financial assumptions in the first simulation year. R602 prints the financial statements and reports.

Both subroutines have the same arguments: a logical indicator for whether the current year is a user-specified summary year (SUM), a logical indicator for whether the first year is being processed (FRSTYR), a logical indicator for whether the last year is being processed (LSTYR), a current year index (KURYR), and a current report index (KURREP). The two programs also have the same common blocks. The common block /CURREP/ stores parameters that specify the report being processed: a list of states in the report (ISTATR(50)), an index to ISTATR that points to the state in process (ISTAPT), and a list of years being reported (IYEAR(50)). Another block /SCENAR/ stores variables for the number of states for which there is data (NSTATE), the number of years for which there is data (NYEAR), the first year of the simulation, e.g., 1980 (NYEAR1), a list of states for which there is data (LSTATE), the title of the scenario (TITLE), the number of reports in the scenario (NREPT), identifiers of all reports (IDR(25)), the number of report sub-indices (INDXS(25)), and report descriptions (DESCR(16,25)). The third common block contains variables read from the SDUMP file: the report identification read (IDS), the report subindex read (IDSUBS), the number of values read from VAL (NVALS), and the buffer array into which the financial variables are read (VAL(805)).

8.2.3.1 R601, Financial Summaries

In this extremely short subroutine, if KURYR equals 1, the program first calls the subroutine HEADRS to print titles and preliminary table headings. (If KURYR does not equal 1, an error message is printed, since R601 should be called only in the first simulation year.) The program then writes a table of financial assumptions. If there is more than one state in a report, this subroutine will be called in the first simulation year for each state.

8.2.3.2 R602, Financial Statements and Reports

If FIRST signals that it is the first year the program has been called for a particular state, N2PRNT, a counter for the number of years' output requested in the report, is set to zero; in subsequent years, N2PRNT is augmented. The counter for the simulation year (IYR) is initialized at zero (if it is the first year being processed (FRSTYR)) or augmented. In the first year, the subroutine HEADRS is called. The values of IPRYR and NXTYR are also set in this section.

Next, the program assigns the items in the array VAL to the variables that represent the various financial accounts. Several of these are base-year values of variables that are computed within R602 in subsequent years. Thus they are assigned to the financial array accounts only in the first year.

The program then prepares to write reports if the present year is the last year being processed (signaled by LSTYR). If not, the program skips the report writing section and goes directly to the RETURN statement. If so, NYEARS, the number of years requested in the present report, is set equal to N2PRNT and N2PRNT is reset to zero, and FIRST is reset to "true". LASTOD, a logical variable that indicates whether the number of years requested in the report is evenly divisible by 10, is set to "false" initially. MAX, the number of years that will be printed on a line of output, is set equal to its maximum value of 10. N, the number of times the report's lines will have to be printed out to accommodate NYEARS, is set at NYEARS/10. Since N is an integer, if NYEARS is evenly divisible by 10, then 10 will always be the appropriate value for MAX. N is correct as it is, and the program proceeds immediately to write the reports. If NYEARS is not evenly divisible by 10, however, N as calculated will be too small and is therefore augmented by 1. In addition, the program calculates a variable

$$LAST = NYEARS - (NYEARS/10 * 10). \qquad \text{[Eq 20]}$$

For example, if NYEARS = 15, N = 2, and LAST = 5. LASTOD is then reset to "true". For each set of reports, the write statements are in loops that count from 1 to N and, within each write statement, a line of values for that variable is printed out by a loop that counts from 1 to MAX. If, however, the counter equals N and LASTOD is true, then MAX is set equal to LAST. In this way, if NYEARS equals 15, the first iteration will write out 10 years of values and the second (and last) iteration will write out five years.

The subroutine completes its tasks by writing out reports in this fashion. In order, the reports are: the balance sheet, the income statement, the statement of retained earnings, the current federal income tax statement, the statement of funds provided and applied, a report on the components of the revenue requirement, and finally the interest coverage and profitability measures. The subroutine HEADRS is called just before each report is written. Examples of each report appear as Table 3-1 and Tables 3-3 through 3-8 of the analytical documentation.

8.3 Data Handling

Table C8-1 summarizes the way data are handled for three of the four financial module operations described above: initialize base year accounts, scan for active construction, and retrieve operating data and calculate required revenue. The fourth operation, fulfill financial needs and prepare financial statements, does not receive data from any of the data groups and is therefore not included in the table.

Table C8-1
FINANCIAL MODULE DATA HANDLING

Data Group	*Access*	*Circumstances*	*Data Elements*	*Variables*
		Initialize Base Year Accounts		
60	GET	First year of simulation	all	
Scenario	GETSCN	First year of simulation	52,53,54	BSYR,NYEAR,RINF
61	GET	First year of simulation	all	
62	GET	First year of simulation	all	
65	GET	First year of simulation	all	
64	GET	Every year except first	all	
		Scan for Active Construction		
23	GET	For every asset under construction	2,3,4,6,9,12, 14,16,18,19,20	LC,S,CONEXP, VEST,CWP,TOTITC
23	PUT	For every asset under construction	14,16,18,19,20	2,3,4,6,9,12LC,S,CONEXP VEST,CWP,TOTITC
32	GET	For every year there is construction in DG 32	10	3,4,5,6,8,9,CONEXP,S,C VEST,CWP,TOTITC
32	PUT	For every year there is construction in DG 32	3,4,5,6,8,9, 10	CONEXP,S,C VEST,CWP,TOTITC
33	GET	For every year there is construction in DG 33	3,4,5,6,8,9, 10	CONEXP,S,C, VEST,CWP,TOTITC
33	PUT	For every year there is construction in DG 33	3,4,5,6,8,9, 10	CONEXP,S,C, VEST,CWP,TOTITC
34	GET	For every year there is construction in DG 34	3,4,5,6,8,9, 10	CONEXP,S,C, VEST,CWP,TOTITC
34	PUT	For every year there is construction in DG 34	3,4,5,6,8,9, 10	CONEXP,S,C, VEST,CWP,TOTITC
		Retrieve Operating Data and Calculate Required Revenue		
15	GET	Every year	1,7,8	GENET,OPREVE,PP
22	GET	Every year	all	
42	GET	Every year	all	
63	GET	Every year	all	
64	GET	Every year except first	all	

Note: See the AUSM design document [2] for descriptions of data groups and elements.

8.4 Subprogram Descriptions

There are five subroutines in the financial module: DEPREC, FINANC, ROUND, R601, and R602.[3] Synopses and calling sequences of these subroutines appear in Table C8-2. Detailed descriptions appear in the following subsections.

8.4.1 Subroutine DEPREC

Called by: FINANC

Calls: ROUND

Arguments: LIFN, LIFT, RBS, AFC, ASSTYP, ETXR, NORMFT, DBR, TCADJ, HADF, IYEAR, DPRATE (inputs); ACDSL1, ACDSL3, RGDP, ACRGDF, DSL1, TXDP, ACBKDF, BKDF (outputs)

Task: Calculates asset depreciation accounts and deferred tax accounts for new assets.

Method: Applies tax laws and regulatory commission guidelines to assets to determine straight-line and accelerated depreciation accounts using both direct construction costs and direct construction costs plus afudc charges. Calculates deferred taxes and tax allowance using the depreciation accounts.

8.4.2 Subroutine FINANC

Called by: MAIN

Calls: DEPREC, GET, PUT

Arguments: ISTATE, IYEAR, ITRACE

Task: Determines the required revenue for the utilities and passes information to R602 for the formulating of the financial statements.

---

[3] Subroutines R601 and R602 are parts of the report-generating program, AUSMR (see Chapter C9), rather than in AUSM itself.

Table C8-2
SUBROUTINE SYNOPSES

Subroutine	*Synopsis*	*Calling Sequence*
DEPREC	Calculates asset depreciation accounts and deferred tax accounts for new assets	FINANC → DEPREC
FINANC	Determines the required revenue for the utilities and passes information to R602 for formulating the financial statements; calculates the financial needs of the utilities and fulfills this need by either issuing or retiring additional debt and preferred and common equity; calculates the interest coverage and profitability ratios	
ROUND	Determines the year of an asset's life when the declining balance accelerated depreciation account switches to straight-line depreciation	FINANC → DEPREC → ROUND
R601	Prints out the statement of financial assumptions	
R602	Constructs the financial statements	

Method: FINANC determines the required revenue for the utilities by using the following equation:

Revenue requirement = *Return to capital + tax allowance + straight-line depreciation + fuel costs + maintenance costs + purchased power costs* [Eq 21]

The fuel costs, maintenance costs, and purchased power costs are passed to FINANC from other parts of the model. The only operation FINANC directly performs on them is to inflate them by the general inflation rate.

To calculate the return to capital, tax allowance, and straight-line depreciation, FINANC keeps track of the construction costs and afudc charges associated with the existing plant, new plant construction, retrofit pollution control construction, and expenditures on transmission, distribution, and general plant.

8.4.3 Subroutine ROUND

Called by: DEPREC

Calls: None

Arguments: CHBK, DBR, N

Task: Determines the year of an asset's life when the declining balance depreciation account switches from accelerated depreciation to straight-line depreciation.

8.4.4 Subroutine R601

Called by: MAIN

Calls: HEADRS

Arguments: FRSTYR, KURYR, KURREP, LASTYR, SUM

Task: Prints statement of financial assumptions

8.4.5 Subroutine R802

Called by:	MAIN
Calls:	HEADRS
Arguments:	FRSTYR, KURREP, KURRYR, LASTYR, SUMYR
Tasks:	Constructs the financial statements.

8.5 Financial Module Variables

The variables used in the financial module are defined in Table C8-3. Additional information about these variables appears in Table C8-4.

8.6 Subprogram Flowcharts

A flowchart of subroutine FINANC is presented as Figure C8-1. Subroutine DEPREC is depicted in Figure C8-2. Figure C8-3 shows the inputs to and outputs of the financial module.

Figure C8-2
SUBROUTINE DEPREC FLOWCHART

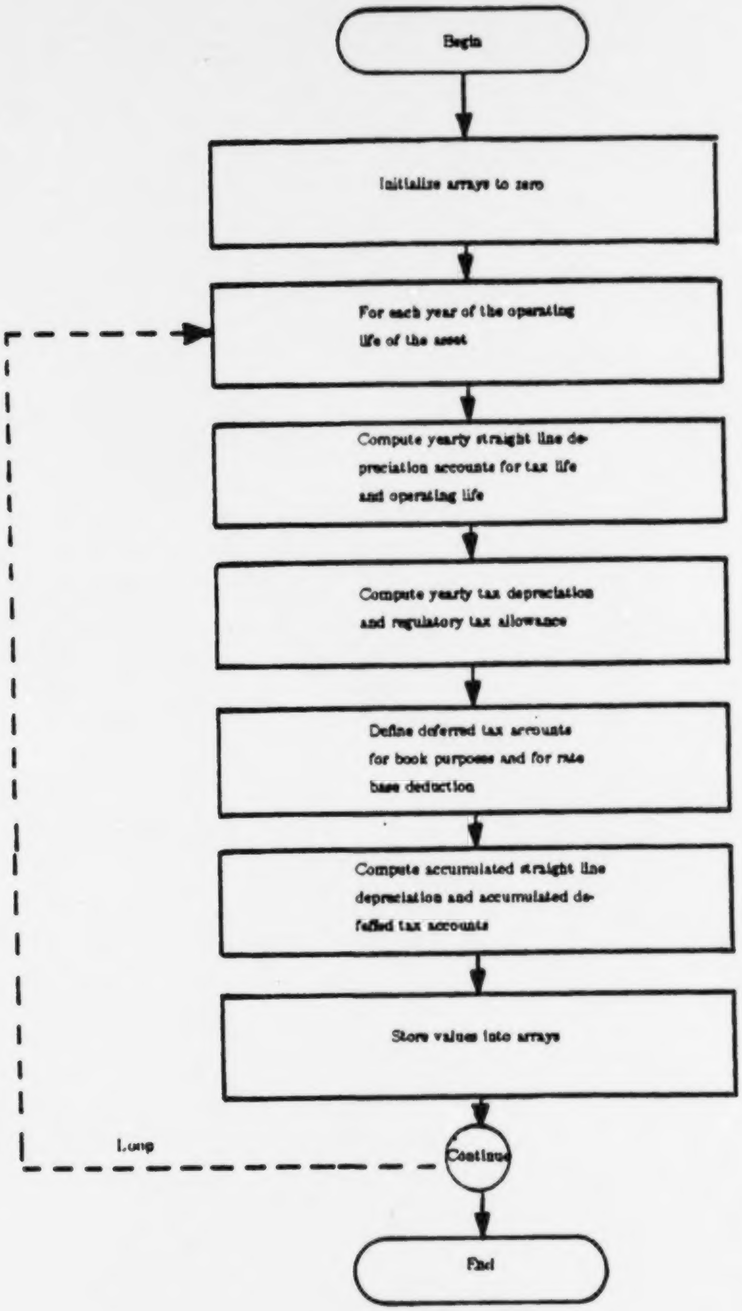
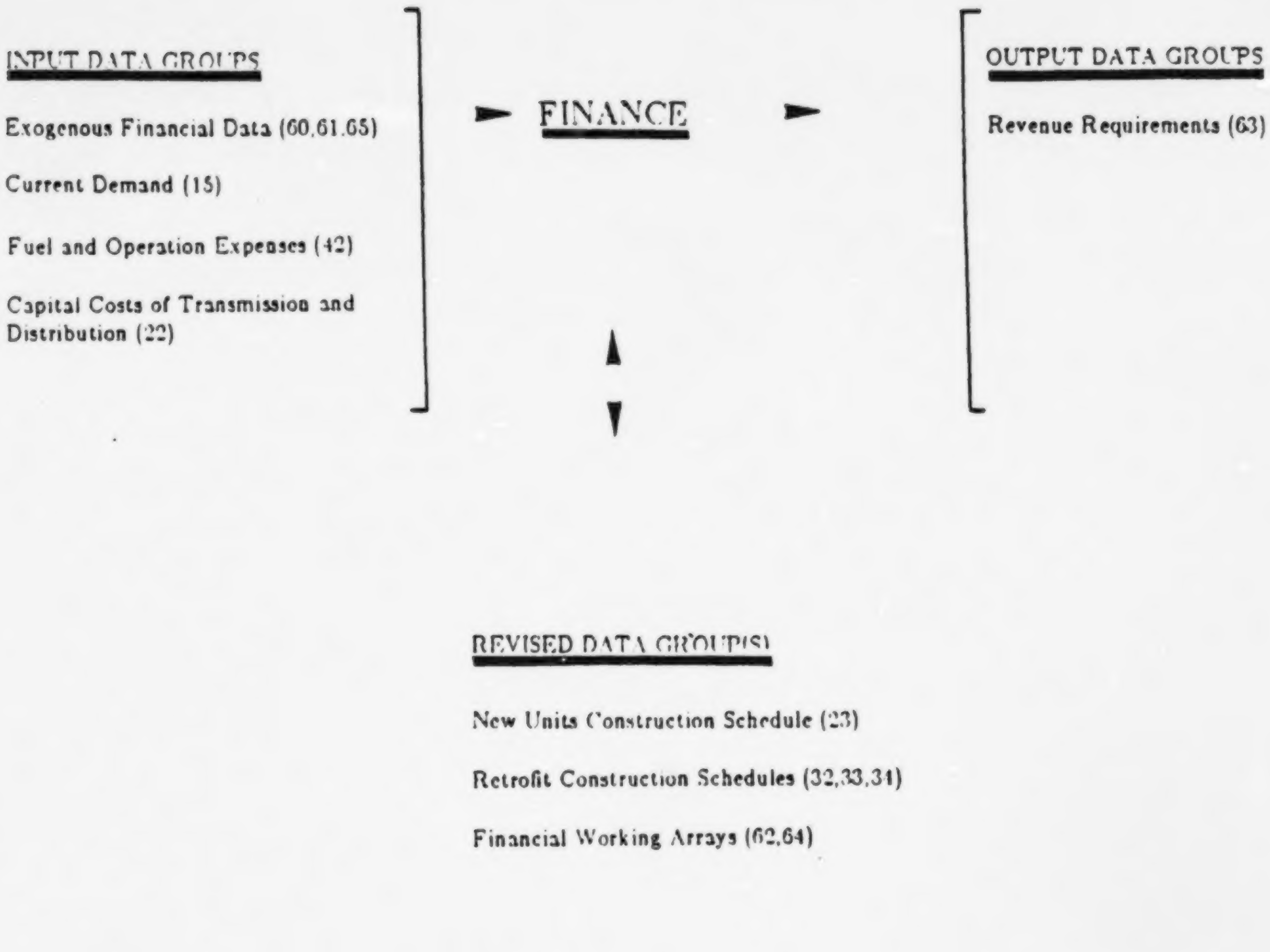

Begin
Initialize arrays to zero
For each year of the operating life of the asset
Compute yearly straight line depreciation accounts for tax life and operating life
Compute yearly tax depreciation and regulatory tax allowance
Define deferred tax accounts for book purposes and for rate base deduction
Compute accumulated straight line depreciation and accumulated deferred tax accounts
Store values into arrays
Loop
Continue
End

Figure C8-3
FINANCE INPUTS AND OUTPUTS



INPUT DATA GROUPS

Exogenous Financial Data (60,61,65)

Current Demand (15)

Fuel and Operation Expenses (42)

Capital Costs of Transmission and Distribution (22)

FINANCE

OUTPUT DATA GROUPS

Revenue Requirements (63)

REVISED DATA GROUP(S)

New Units Construction Schedule (23)

Retrofit Construction Schedules (32,33,34)

Financial Working Arrays (62,64)

Table C8-3
VARIABLE DESCRIPTIONS

Variable	*Unit*	*Description*
ABKDF	Million $	Temporary variable used for calculating ACBKDF
ACBKDF	Million $	Accumulated deferred income tax for book purposes or for full normalization for a particular asset; equals accumulation of actual tax depreciation (TXDEPR) minus straight-line (construction cost, operating life) times the income tax rate
ACCTR	Million $	Accounts receivable; combines with CASH to make ASSCAO
ACDFTX	Million $	Accumulated deferred taxes in base year
ACDSL1	Million $	Accumulated straight-line depreciation (construction cost plus afudc, operating life) for a particular asset in a given Year
ACDSL3	Million $	Accumulated straight-line depreciation (construction cost, operating life) for a particular asset in a given year
ACITC	Million $	Accumulated investment tax credits for regulatory commission purposes (for deduction from the rate base); may be only a fraction of total accumulated investment tax credit from electric investment; appears in the output on the regulatory economics statement
ACRGDF	Million $	Accumulated deferred income tax for rate base adjustment for a particular asset in each simulation year; equals accumulation of TXDEPR minus REGDPE times the tax rate
ACTCT	Million $	Accumulated total investment tax credit for all investments; appears in the output on the balance sheet
ADDE	Million $	Total direct construction costs and afudc charges in a given year excluding pollution control equipment; appears in the output on the statement of funds provided and funds applied

Table C8-3 (contd.)

Variable	*Unit*	*Description*
ADDNET	Million $	Additions to utility plant in base year, net of afudc
ADDP	Million $	Total direct construction costs and afudc charges for pollution control equipment in a given year; appears in the output on the statement of funds provided and funds applied
ADFBK	Million $	Accumulated total deferred income taxes for book purposes; equals accumulation of accelerated depreciation (construction cost, tax life) minus straight-line depreciation (construction cost, operating life) times tax rate; accumulated over assets as well as over time; appears in the output on the balance sheet
ADFRGE	Million $	Accumulated deferred income taxes for deduction from rate base; equals accumulation of TXDEPR minus REGDPE times the tax rate; accumulated over assets as well as over time; appears in the output on the regulatory economics statement
ADJRBS	Million $	Adjusted rate base; TOTRBS minus accumulated deferred taxes (ADFRGE) and accumulated investment tax credits (ACITC) in the normalization case; for flow-through accounting, ADJRBS equals TOTRBS; appears in the output on the regulatory economics statement
ADPRBE	Million $	Accumulated straight-line depreciation (construction cost plus afudc, operating life); accumulated over all facilities and over time; appears in the output on the balance sheet
ADPTBE	Million $	Accumulated straight-line depreciation (construction cost, operating life); accumulated over all facilities and over time
ADS1	Million $	Temporary variable for calculating ACDSL1
ADS3	Million $	Temporary variable for calculating ACDSL3
AFC	Million $	Total afudc on a particular asset

Table C8-3 (contd.)

Variable	*Unit*	*Description*
AFDCD	Million $	Afudc-debt for a particular asset in a given Year
AFDCE	Million $	Afudc-equity for a particular asset in a given Year
AFUDCD	Million $	Afudc-debt accumulated over all projects under construction in a given year; appears in the output on the income statement and on the statement of funds provided and funds applied
AFUDCE	Million $	Afudc-equity accumulated over all assets under construction in a given year; appears in the output on the income statement and on the statement of funds provided and funds applied
AITC	Million $	Yearly amortization of the accumulated investment tax credit that is deducted from rate base in normalized accounting
AMF	Fraction	Yearly amortization factor; the portion of the historic debt retired each year
ARGDF	Million $	Temporary variable for calculating ACRGDF
ASSCAO	Million $	Current and other assets; equals ACCTR + CASH; appears in the output on the balance sheet
ASSTOT	Million $	Total assets; equals PELTOT + OTHASS + ASSCAO; appears in the output on the balance sheet
ASSTYP	Integer	Identifies type of asset
BKDEF	Million $	Temporary variable for calculating BKDF
BKDF	Million $	Basis for deferred tax on income statement; equals TXDP minus straight-line depreciation (construction cost, operating life) times the income tax rate for a particular asset
BSWCAP	Million $	Base year working capital, equals ASSCAO(1) - LIACAO(1)
BSYR	Year	Base year; corresponds to the year for which actual data are input into the model (e.g., 1980)

Table C8-3 (contd.)

Variable	*Unit*	*Description*
C	Year	The year in which a new asset begins construction
CASH	Million $	Cash; combines with ACCTR to make ASSCAO; will be greater than zero only if all debt has been retired
CCO	Million $	Direct construction costs of an asset; used in setting up the depreciation accounts
CDIV	Million $	Dividends paid on common stock; in most years equals 0.15 * RETBEG, but may be larger if utilities have excess funds; appears in the output on the retained earnings statement and on the statement of funds provided and funds applied
CEQPC	Fraction	Fraction of capitalization that is common equity
CEQTOT	Million $	Total common stock issued; equals OLDCEQ + NWCEQ
CHAITC	Million $	Change in investment tax credit shown on the balance sheet during a year; equals ACTCT - ACTCT(LSTYR) for every year but the first year; appears in the output on the statement of funds provided and funds applied
CHK	Integer	Temporary variable for calculating CHK1 and CHK2
CHKBK	Integer	Temporary variable for calculating CHK1 and CHK2
CHK1	Integer	Check point for switch from accelerated depreciation to straight-line depreciation when using declining balance accelerated depreciation and the tax life of the asset
CHK2	Integer	Check point for switch from accelerated depreciation to straight-line depreciation when using declining balance accelerated depreciation and the operating life of the asset

Table C8-3 (contd.)

Variable	*Unit*	*Description*
CHWCAP	Million $	Change in working capital during a year; if it is the first year of the simulation CHWCAP equals WCAP - BSWCAP; if it is a later year in the simulation CHWCAP equals WCAP - WCAP(LSTYR); appears in the output on the statement of funds provided and funds applied
COMBAL	Million $	Balance left from net income for common shareholders; equals NETINC - PDIV
COMTOT	Million $	Total common stock equity; equals CEQTOT + RETERN; appears in the output on the balance sheet
CONEXD	Million $	Direct construction expense for distribution plant in a given year
CONEXG	Million $	Direct construction expense for general plant in a given year
CONEXP	Million $	Direct construction expense for a particular asset in a given year
CONEXT	Million $	Direct construction expense for transmission plant in a given year
CORR	Million $	Correction to total liabilities made for the first year balance of the balance sheet; appears in the output on the balance sheet
COV1...COV4	Real	Interest coverage ratios; each of the four is computed by dividing a different definition of income by interest expense; appears in the output on the statement of interest coverage and profitability ratios
CR	Million $	Capital recovery for required revenue determination; equals RD + RC + RP + RBDP
CRET	Fraction	Rate of return to common stock
CWIPE	Million $	Construction work in progress (construction cost plus afudc); equals CWPE + CWPP; appears in the output on the balance sheet

Table C8-3 (contd.)

Variable	*Unit*	*Description*
CWP	Million $	Construction work in progress; accumulated direct construction costs plus afudc for a particular asset in a given year
CWPE	Million $	Construction work in progress (construction cost plus afudc) for all non-pollution control electric assets under construction in a given Year
CWPP	Million $	Construction work in progress (construction cost plus afudc) for all pollution control assets under construction in a given year
DA1	Million $	Temporary variable for calculating accelerated depreciation (construction cost, tax life)
DA2	Million $	Temporary variable for calculating accelerated depreciation (construction cost, operating life)
DBLR	Fraction	Amount by which the straight-line depreciation rate can be multiplied in computing accelerated depreciation for tax purposes under the 1981 Tax Recovery Act and 1982 revisions; equals 1.5
DBLRO	Fraction	Same definition as for DBLR except that it is for assets on-line prior to 1981; equals 2.0
DBR	Fraction	DBLR (or DBLRO) value in effect the year a new asset comes on-line
DB1	Fraction	Temporary variable for calculating the accelerated depreciation basis when the declining balance method is used over the shortest ADR tax life
DB2	Fraction	Temporary variable for calculating the accelerated depreciation basis when the declining balance method is used over the normal operating life
DCEQ	Million $	Amount of common equity that would keep common equity, preferred equity, and debt levels in their original proportions of total capitalization

Table C8-3 (contd.)

Variable	*Unit*	*Description*
DDEBT	Million $	Amount of debt that would keep common equity, preferred equity, and debt levels in their original proportions of total capitalization
DEBTCH	Million $	Amount of debt to be retired in a year in addition to the amount of debt that reaches maturity in that year (DRETIR)
DEDTC	Million $	Yearly amortization of total accumulated investment tax credits
DEN1	Million $	Denominator used in the computation of interest coverage ratios; equals LTDEXP
DEN2	Million $	Denominator used in the computation of profitability ratios one and two; equals COMTOT + PEQTOT
DEN3	Million $	Denominator used in the computation of profitability ratios three and four; equals NETPE
DFTXBK	Million $	Deferred tax for income statement; equals accelerated depreciation for all assets (construction cost, tax life) minus straight-line depreciation for all assets (construction cost, operating life) times the income tax rate; appears in the output on the income statement and on the statement of funds provided and funds applied
DNORME	Million $	Straight-line (construction cost plus afudc, operating life) depreciation on all electric assets in each simulation year; appears in the output on the income statement and on the statement of funds provided and funds applied
DOEXP	Million $	Direct operating expenses; equals PP + fuel costs + maintenance costs + OPEXPO; appears in the output on the federal income tax statement

Table C8-3 (contd.)

Variable	*Unit*	*Description*
DPEQ	Million $	Amount of preferred equity that would keep common equity, preferred equity, and debt levels in their original proportions of total capitalization
DPRATE	Fraction	Depreciation rate schedule under the new tax law for a particular asset
DP101	Fraction	Tax depreciation rate schedules for 10-year tax lives as published in the 1981 Tax Act and amended in the 1982 Tax Act to apply to all future years
DP151	Fraction	Tax depreciation rate schedules for 15-year tax lives as published in the 1981 Tax Act and amended in the 1982 Tax Act to apply to all future years
DRET	Million $	Debt to be retired in base year
DRETIR	Million $	Debt to be retired in each simulation year (assumes 20-year bonds); appears in the output on the statement of funds provided and funds applied
DLS1	Million $	Straight-line depreciation (construction cost plus afudc, operating life) for a particular asset in a given year
DSPOL	Million $	Temporary variable for calculating the accelerated depreciation for retrofit pollution control equipment
DS1	Million $	Temporary variable for calculating DSL1
DS2	Million $	Temporary variable for calculating straight-line depreciation
DS3	Million $	Temporary variable for calculating straight-line depreciation
DTPC	Fraction	Fraction of capitalization that is debt
ELIG	Fraction	Fraction of asset type eligible for investment tax credit

Table C8-3 (contd.)

Variable	*Unit*	*Description*
EQPC	Fraction	Fraction of capitalization that is equity; equals CEQPC + PEQPC
ETXR	Fraction	Combined effective federal and state corporate income tax rate; equals FTXR * (1 - STXR) + STXR
EXPTOT	Million $	Total operating expenses; equals DOEXP + DNORME + ITXR + GRTX + PTX + SSOTX; appears in the output on the income statement
FDAPPL	Million $	Total funds applied; equals ADDE + ADDP + DRETIR - AFUDCD - AFUDCE + PDIV + CDIV + CHWCAP; appears in the output on the statement of funds provided and funds applied
FDEDS	Million $	Federal income tax deductions; equals SDEDS + SITX
FDPROV	Million $	Total funds provided; equals NETINC + DNORME + DFTXBK - AFUDCD - AFUDCE + NWDT + NWCEQ + NWPEQ + CHAITC; appears in the output on the statement of funds provided and funds applied
FIRST	Binary	Denotes whether or not finance is being called for the first year for a given state
FITX	Million $	Actual federal income tax expense; equals FTI * FTXR - ITC; appears in the output on the federal income tax statement
FNEEDS	Million $	Financial needs
FRITC	Fraction	Portion of investment tax credit that is normalized
FRSTYR	Binary	Denotes whether or not this is the first year the report writers are being called
FTI	Million $	Federal taxable income; equals OPREVE - FDEDS; appears in the output on the federal income tax statement
FTXR	Fraction	Federal corporate income tax rate

Table C8-3 (contd.)

Variable	*Unit*	*Description*
FUELC	Million $	Coal fuel cost; appears in the output on the income statement and on the regulatory economics statement
FUELDO	Million $	Distillate oil fuel cost; appears in the output on the income statement and on the regulatory economics statement
FUELN	Million $	Nuclear fuel cost; appears in the output on the income statement and on the regulatory economics statement
FUELNG	Million $	Natural gas fuel cost; appears in the output on the income statement and on the regulatory economics statement
FUELO	Million $	Other fuel cost; appears in the output on the income statement and on the regulatory economics statement
FUELRO	Million $	Residual oil fuel cost; appears in the output on the income statement and on the regulatory economics statement
GENET	Billion KWh	Total sales of electricty
GRSPE	Million $	Gross electric plant in the base year; used to initialize the depreciation accounts for historic plant
GRSSPE	Million $	Gross electric utility plant in service; appears in the output on the balance sheet
GRSSRB	Million $	Gross electric utility plant in the rate base; appears in the output on the regulatory economics statement
GRTX	Million $	Gross receipts tax; equals OPREVE * GRTXR; appears in the output on the income statement and on the federal income tax statement
GRTXAL	Million $	The portion of the revenue requirement that allows for the recovery of the gross receipts tax; equals GRTXR * REVRQ * (1 - ETXR)
GRTXR	Fraction	Gross receipts tax rate

Table C8-3 (contd.)

Variable	*Unit*	*Description*
H	Fraction	Temporary variable for calculating the amount of historic debt to be retired in any year in the future; historic debt is amortized over a 20-year period
HADF	Fraction	Percentage of the total historic plant for a state using accelerated depreciation for tax purposes rather than straight-line depreciation
IAGEBK	Year	Age of historic gross electric plant that most closely approximates for book purposes the depreciation schedule as if the historic plant was a single asset with a 35-year life
IBRIDG	Integer	Link between the asset type categories used for generation and the asset type categories used for depreciation schedules
ICONST	Integer	Variable to designate the four data groups for new plant construction and the three types of retrofit pollution control equipment
ICUM	Real	Variable to denote how afudc is compounded: ICUM = 0 if afudc is not earned on past afudc, ICUM = 1 if afudc is earned on past afudc
ICWIP	Real	Variable to denote whether cwip is in the rate base: ICWIP = 0 if afudc is calculated according to ICUM and cwip is not allowed in the rate base; ICWIP = 1 if afudc is equal to zero and cwip is allowed in the rate base
IDGRP	Integer	Data group identifier for trace output
IENTRY	Integer	Number to identify the new asset that is being processed
IGRP	Integer	Data group that contains information on the new asset being processed
IPRYR	Year	Variable to print out the year (e.g., 1980)
IRATE	Real	Variable to denote how afudc is computed: IRATE = 0 if afudc-debt is computed net of tax; IRATE = 1 if afudc-debt is computed before tax

Table C8-3 (contd.)

Variable	*Unit*	*Description*
ISTATE	Integer	FIPS code of the state presently being processed
ITC	Million $	Amount of investment tax credit earned during the year; sum of ZITC for each asset in each simulation year; appears in the output on the income statement and on the federal income tax statement
ITRACE	Integer	Variable denoting the amount of trace output desired
ITXP	Million $	Income tax paid; equals FITX + SITX; appears in the output on the income statement
ITXR	Million $	Income tax reported; equals ITXP + DFTXBK + ITC - TCTKN; appears in the output on the income statement
IYEAR	Year	Current year of simulation
IYEARR	Integer	List of indices of years selected for inclusion in current report
IYEARS	Year	Year index from SDUMP file
IYR	Integer	Current year index
JYR	Integer	Year index used for writing reports
KKO	Million $	Variation on CCO in depreciation to allow for half-year convention in depreciation accounts
KURREP	Integer	Current report index
KURYR	Integer	Current year index
LAST	Integer	Number of years to be included on the final page of each financial report
LASTOD	Binary	Logical variable to delineate whether the number of years to print in the reports can be divided evenly by 10 (the normal number of Years shown on each page of the financial reports)
LASTYR	Binary	Logical variable to indicate whether the last Year is being processed

Table C8-3 (contd.)

Variable	*Unit*	*Description*
LIACAO	Million $	Notes and other current liabilities; appears in the output on the balance sheet
LIATOT	Million $	Total capitalization, liabilities, and credits; equals CAPTOT + ADFBK + ACTCT + LIACAO; appears in the output on the balance sheet
LIFN	Years	Operating life for a new asset
LIFT	Years	Tax life for a new asset
LITC	Years	Period over which investment tax credit is amortized
LN	Years	Operating life for each asset type
LSTATE	Integer	List of state FIPS codes
LSTYR	Integer	Year index of previous year
LT	Years	Tax life for each asset type under the asset depreciation range (pre-1981) system
LTDEXP	Million $	Interest expense on long-term debt; equals RINT * LTDTOT; appears in the output on the income statement and on the federal income tax statement
LTDTOT	Million $	Total long-term debt; equals OLDT + NWDT
LTN	Years	Tax life of an asset allowed by the 1981 Tax Recovery Act
MAX	Integer	Number of years to be printed on the present page of financial output
NETINC	Million $	Net income for income statement; equals OPREVE - EXPTOT + OTHINC - TOTINT; appears in the output on the income statement, on the retained earnings statement, and on the statement of funds provided and funds applied
NETPE	Million $	Net electric plant in service; equals GRSSPE - ADPRBE, appears in the output on the balance sheet

Table C8-3 (contd.)

Variable	*Unit*	*Description*
NETPLE	Million $	Net electric plant in the base year; used to calculate the appropriate equivalent book age of the gross plant as if gross plant was a single asset with a 35-year book life
NORMFT	Real	Variable for different regulatory tax accounting procedures; NORMFT = 1 if the accounting procedure is for full normalization; NORMFT = 2 if the accounting procedure is for flow-through accounting; NORMFT = 3 if the accounting procedure is for partial normalization
NSCHED	Integer	Number of projects presently under construction
NWCEQ	Million $	New common stock issued; appears in the output on the balance sheet and on the statement of funds provided and funds applied
NWDT	Million $	New long-term debt issued; appears in the output on the statement of funds provided and funds applied
NWPEQ	Million $	New preferred stock issued; appears in the output on the balance sheet and on the statement of funds provided and funds applied
NXTYR	Integer	Year index for the next year
NYEAR	Years	Number of years in AUSM scenario
NYEARS	Years	Number of years requested in the present report
N2PRNT	Integer	Number of years requested in the present report
OASS	Million $	Other assets; assets owned by the utility not associated with electricity production, distribution, or sale, only calculated in the first year and equals TOTASS - ASSCAO(1) - NETPLE - CWPE(1); data have been adjusted so that OASS = zero
OLDCEQ	Million $	Common stock issued prior to each simulation year; appears in the output on the balance sheet

Table C8-3 (contd.)

Variable	*Unit*	*Description*
OLDPEQ	Million $	Preferred stock issued prior to each simulation year; appears in the output on the balance sheet
OLDT	Million $	Total outstanding debt as of each simulation year; equals LTDTOT(LSTYR) - DRETIR
OPEXPO	Million $	Administrative, customer, and other costs; appears in the output on the income statement, on the federal income tax statement, and on the regulatory economics statement
OPREVE	Million $	Operating revenues; appears in the output on the income statement
OPRXO	Million $	Total operation and maintenance expense for transmission, distribution, general plant, and intangibles
OPRXPC	Million $	Total operation and maintenance expense for pollution control
OPRX1	Million $	Total plant operation and maintenance expense
OTHASS	Million $	Assets owned by the utility other than those related to the generation, distribution, and sale of electricity; assumed to be equal to the base year value for each subsequent year; is set equal to OASS and therefore equals zero each year
OTHINC	Million $	Other income; equals AFUDCE; appears in the output on the income statement
PDIV	Million $	Dividends paid on preferred stock; equals OLDPEQ * PRET; appears in the output on the retained earnings statement and on the statement of funds provided and funds applied
PELTOT	Million $	Total electric utility plant assets; equals NETPE + CWIPE; appears in the output on the balance sheet
PEQPC	Fraction	Fraction of capitalization that is preferred stock

Table C8-3 (contd.)

Variable	*Unit*	*Description*
PEQTOT	Million $	Total preferred stock; equals OLDPEQ + NWPEQ; appears in the output on the balance sheet
PP	Million $	Cost of purchased and interchanged electric power; appears in the output on the income statement and on the regulatory economics statement
PPFRC	Fraction	Percentage of total revenue requirement attributable to purchased power
PRET	Fraction	Rate of return to preferred stock
PROF1...PROF4	Fraction	Profitability ratios; computed by dividing different definitions of income by total equity for PROF1 and PROF2 or by dividing income by net plant for PROF3 and PROF4; appears in the output on the statement of interest coverage and profitability ratios
PTQFC	Fraction	Percentage of total revenue requirement attributable to coal fuel cost recovery
PTQFDO	Fraction	Percentage of total revenue requirement attributable to distillate oil fuel cost recovery
PTQFN	Fraction	Percentage of total revenue requirement attributable to nuclear fuel cost recovery
PTQFNG	Fraction	Percentage of total revenue requirement attributable to natural gas fuel cost recovery
PTQFO	Fraction	Percentage of total revenue requirement attributable to other fuel cost recovery
PTQFRO	Fraction	Percentage of total revenue requirement attributable to residual oil fuel cost recovery
PTQK	Fraction	Percentage of total revenue requirement attributable to the return to capital; the residual
PTQL	Fraction	Percentage of total revenue requirement attributable to labor and operation and maintenance cost recovery

Table C8-3 (contd.)

Variable	*Unit*	*Description*
PTX	Million $	Property taxes: equal to TBASE • PTXR; appears in the output on the income statement, on the federal income tax statement, and on the regulatory economics statement
PTXR	Fraction	Property tax rate
RADCD	Fraction	Afudc-debt rate; equals RINT • DTPC
RADCE	Fraction	Afudc-equity rate; equals ROE • EQPC
RBADJ	Million $	Adjustments to rate base; equals accumulated straight-line depreciation (ADPRBE) plus accumulated deferred taxes (ADFRGE) plus accumulated investment tax credit (ACITC); the last two terms equal zero for flow-through accounting; appears in the output on the regulatory economics statement
RBDP	Million $	Straight-line depreciation (construction cost plus afudc, operating life), a component of revenue requirement
RBS	Million $	Total gross investment cost (construction cost plus afudc) for a particular asset
RC	Million $	Allowed return to common equity for revenue requirement determination; equals ADJRBS • CRET • CEQPC; appears in the output on the regulatory economics statement
RD	Million $	Allowed return to debt for revenue requirement determination; equals ADJRBS • RINT • DTPC; appears in the output on the regulatory economics statement
REGDPE	Million $	Depreciation deduction for regulatory commission tax allowance; for post-1980 assets it equals accelerated depreciation for all electric assets using construction costs and operating life
REGTC	Million $	Base year values of accumulated investment tax credit earned from electric investments that is normalized by the state regulatory commission
RETBEG	Million $	Retained earnings: beginning of year; equals RETERN(LSTYR); appears in the output on the retained earnings statement

Table C8-3 (contd.)

Variable	*Unit*	*Description*
RETERN	Million $	Retained earnings; end of year; appears in the output on the balance sheet and on the retained earnings statement
RETPCT	Fraction	Percentage of total common equity caused by retained earnings
RETRO	Real	Variable for reading in data on the three different types of retrofit pollution control equipment
REVRQ	Million $	Revenue requirement for price determination; appears in the output on the regulatory economics statement
RGD	Million $	Temporary variable for calculating RGDP
RGDF	Million $	Temporary variable for calculating ACRGDF
RGDP	Million $	Depreciation deduction for regulatory commission tax allowance; used to compute REGDPE
RINF	Fraction	Assumed rate of general inflation
RINFF	Real	Inflation factor to convert 1980 (base year) dollars to nominal dollars in any given year
RINT	Fraction	Interest rate on long-term debt
ROE	Fraction	Rate of return to equity for afudc and required revenue calculations; a weighted average of PRET and CRET
RP	Million $	Allowed return on preferred equity for revenue requirement determination; equals ADJRBS • PRET • PEQPC; appears in the output on the regulatory economics statement
RVQ	Million $	Revenue requirement for price determination in 1980 (base year) dollars; for any year RVQ equals REVRQ deflated (divided) by RINFF
S	Year	Year in which a new asset begins operation

Table C8-3 (contd.)

Variable	*Unit*	*Description*
SDEDS	Million $	Deductions from income for calculating state taxable income: equals PP + fuel costs + maintenance costs OPEXPO + GRTX + SSOTX + PTX + TXDEPR + LTDEXP
SITX	Million $	State income tax due in a given year: equals STI * STXR; appears in the output on the federal income tax statement
SOURCO	Million $	Other funds provided: equals FDAPPL - FDPROV; appears in the output on the statement of funds provided and funds applied
SSOTX	Million $	Social security and other taxes; equals SSPC *OPREVE
SSPC	Fraction	Tax rate for social security and other taxes
STI	Million $	Taxable income for calculating state income taxes: equals OPREVE - SDEDS
STXR	Fraction	State income tax rate for electric utilities
SUM	Binary	Logical variable to indicate whether the current year is a user-specified summary year
SUMM	Million $	Sum of fuel costs, operating costs, and non-income taxes
SUMRT	Million $	Accumulates the additional debt retired when financial needs are negative
SUMYR	Binary	Variable to indicate whether the year currently being processed is to be shown in the output
TBASE	Million $	Basis for tax depreciation and property tax; equals sum of direct construction costs for all plants on-line minus ADPTBE; for historical plant equals GRSSPE * TBSPC
TBSPC	Fraction	Fraction of historical gross plant exclusive of afudc
TCADJ	Million $	Reduction of accelerated depreciation basis in conformity with 1982 tax law revisions; equals half of the investment tax credit earned by the asset

Table C8-3 (contd.)

Variable	*Unit*	*Description*
TCTKN	Million $	Amount of investment tax credit taken in determining income for book purposes; appears in the output on the income statement
TDCWIP	Million $	Amount of cwip left over in the first year of simulation when known construction costs have been subtracted from the cwip that is read in the data; TDCWIP is amortized into GRSSPE and GRSSRB in equal parts over a five-year period
TDVEST	Million $	Amount of non-afudc cost in TDCWIP in the first year; equals TDCWIP (from year one) * TBSPC
TF	Million $	Federal income tax allowance for required revenue determination; appears in the output on the regulatory economics statement
TOTASS	Million $	Total electric and current assets in the base year for the electric utilities in a given state
TOTINT	Million $	Total interest expense for income statement; equals LTDEXP - AFUDCD; appears in the output on the income statement
TOTITC	Million $	Accumulated investment tax credit earned by a particular asset
TOTRBS	Million $	Rate base: construction costs plus afudc on electric plant in service, net of accumulated depreciation; equals GRSSRB - ADPRBE
TOTTC	Million $	Base year value for accumulated investment tax credit earned from electric investments
TS	Million $	State income tax allowance for REVRQ determination; appears in the output on the regulatory economics statement
TXDEPR	Million $	Actual income tax deduction (usually accelerated depreciation (construction cost, tax life) in each simulation year on total assets; appears in the output on the federal income tax statement
TXD	Million $	Temporary variable for calculating TXDP

Table C8-3 (contd.)

Variable	*Unit*	*Description*
TXDP	Million $	Actual income tax depreciation deduction (usually accelerated depreciation (construction cost, tax life)) for a particular asset in a given year
VAL	Million $	Data values read from SDUMP file
VEST	Million $	Accumulated direct construction cost for a particular asset
WCAP	Million $	Working capital; equals ASSCAO - LIACAO
ZITC	Million $	Investment tax credit earned by a particular asset in a given year
ZITCR	Fraction	Investment tax credit rate

Table C8-4
VARIABLE INFORMATION

Variable	Type	Dimension	Unit	Storage Location	Data Group Accessed From[a]	Accessed By
ABKDF	real	1	$	DEPREC		DEPREC
ACBKDF	real	35	$	argument		FINANC, DEPREC(S)[b]
ACCTR	real	30	$	R602		R602
ACDFTX	real	1	$	/FINSTA/	65	FINANC
ACDSL1	real	35	$	argument		FINANC, DEPREC(S)
ACDSL3	real	35	$	argument		FINANC, DEPREC(S)
ACITC	real	30	$	//[c]	64	FINANC(S), R602
ACRGDF	real	35	$	argument		FINANC, DEPREC(S)
ACTCT	real	30	$	//	64	FINANC(S), R602
ADDE	real	1/30	$	FINANC, R602		FINANC(S), R602
ADDNET	real	1	$	/FINSTA/	65	FINANC
ADDP	real	1/30	$	FINANC, R602		FINANC(S), R602
ADFBK	real	30	$	//	64	FINANC(S), R602
ADFRGE	real	30	$	//	64	FINANC(S), R602
ADJRBS	real	1/30	$	FINANC, R602		FINANC(S), R602
ADPRBE	real	30	$	//	64	FINANC(S), R602
ADPTBE	real	30	$	//	64	FINANC(S)
ADS1	real	1	$	DEPREC		DEPREC
ADS3	real	1	$	DEPREC		DEPREC
AFC	real	1	$	argument		FINAC(S), DEPREC
AFDCD	real	1	$	FINANC		FINANC
AFDCE	real	1	$	FINANC		FINANC
AFUDCD	real	1/30	$	FINANC, R602		FINANC(S), R602
AFUDCE	real	1/30	$	FINANC, R602		FINANC(S), R602
AITC	real	1/30	$	FINANC		FINANC
AMF	real	1	$	FINANC		FINANC
ARGDF	real	1	$	DEPREC		DEPREC
ASSCAO	real	1/30	$	/FINSTA/	65	FINANC(S), R602
ASSTOT	real	30	$	R602		R602
ASSTYP	integer	1		argument		FINANC, DEPREC

Table C8-4 (con't)

Variable	Type	Dimension	Unit	Storage Location	Data Group Accessed From[a]	Accessed By
BKDEF	real	1	$	DEPREC		DEPREC
BKDP	real	35	$	argument		FINANC, DEPREC(S)
BSWCAP	real	1	$	/FINSTA/	65	FINANC, R602
BSYR	integer	1	year	FINANC		FINANC
C	real	1	year	FINANC		FINANC
CASH	real	30	$	R602		R602
CCD	real	1	$	DEPREC		DEPREC
CDIV	real	30	$	R602		R602
CEQFC	real	1	fraction	/FINSTA/	61	FINANC, R602
CEQTOT	real	30	$	R602		R602
CHAITC	real	30	$	R602		R602
CHK	integer	1		ROUND		ROUND
CHKBK	real	1		argument		ROUND
CHK1	real	1		argument		DEPREC, ROUND(S)
CHK2	real	1		argument		DEPREC, ROUND(S)
CHWCAP	real	30	$	R602		R602
COMBAL	real	30	$	R602		R602
COMTOT	real	30	$	R602		R602
CONEXD	real	1	$	//	22	FINANC
CONEXG	real	1	$	//	22	FINANC
CONEXP	real	1	$	FINANC		FINANC
CONEXT	real	1	$	//	22	FINANC
CORR	real	1	$	R602		R602
COV1	real	30	fraction	R602		R602
COV2	real	30	fraction	R602		R602
COV3	real	30	fraction	R602		R602
COV4	real	30	fraction	R602		R602
CR	real	1	$	FINANC		FINANC
CRET	real	1	fraction	/FINSTA/	62	FINANC, R602
CWIPE	real	1/30	$	FINANC, R602		FINANC(S), R602
CWP	real	1	$	FINANC		FINANC

Table C8-4 (con't)

Variable	Type	Dimension	Unit	Storage Location	Data Group Accessed From[a]	Accessed By
CWPE	real	1	$	/FINSTA/	65	FINANC
CWPP	real	1	$	/FINSTA/	65	FINANC
DA1	real	1	$	DEPREC		DEPREC
DA2	real	1	$	DEPREC		DEPREC
DBLR	real	30	fraction	/FINNAT/	60	FINANC
DBLRO	real	1	fraction	/FINNAT/	60	FINANC
DBR	real	1	fraction	argument		DEPREC(S), ROUND
DB1	real	1	fraction	DEPREC		DEPREC
DB2	real	1	fraction	DEPREC		DEPREC
DCEQ	real	1	$	R602		R602
DDEBT	real	1	$	R602		R602
DEBTCH	real	1	$	R602		R602
DEDTC	real	1	$	FINANC		FINANC
DEN1	real	30	$	R602		R602
DEN2	real	30	$	R602		R602
DEN3	real	30	$	R602		R602
DFTXBK	real	30	$	//	64	FINANC(S), R602
DNORME	real	30	$	//	64	FINANC(S), R602
DOEXP	real	30	$	R602		R602
DPEQ	real	1	$	R602		R602
DPRATE	real	15	fraction	argument		FINANC(S), DEPREC
DP101	real	15	fraction	/FINNAT/	60	FINANC
DP151	real	15	fraction	/FINNAT/	60	FINANC
DRET	real	1	$	/FINSTA/	65	FINANC
DRETIR	real	30/50	$	//	64	FINANC(S), R602
DSL1	real	35	$	argument		FINANC, DEPREC(S)
DSPOL	real	1	$	DEPREC		DEPREC
DS1	real	1	$	DEPREC		DEPREC
DS2	real	1	$	DEPREC		DEPREC
DS3	real	1	$	DEPREC		DEPREC
DTPC	real	1	fraction	/FINSTA/	61	FINANC, R602

Table C8-4 (con't)

Variable	Type	Dimension	Unit	Storage Location	Data Group Accessed From[a]	Accessed By
ELIG	real	7	fraction	/FINNAT/	60	FINANC
EQPC	real	1	fraction	FINANC		FINANC
ETXR	real	1	fraction	argument		FINANC(S), DEPREC
EXPTOT	real	30	$	R602		R602
FDAPPL	real	30	$	R602		R602
FDEDS	real	30	$	R602		R602
FDPROV	real	30	$	R602		R602
FIRST	logical	1	binary	argument		FINANC(S), R602
FITX	real	30	$	R602		R602
FNEEDS	real	30	$	R602		R602
FRITC	real	1	fraction	FINANC		FINANC
FRSTYR	logical	1	binary	argument		R601, R602
FTI	real	30	$	R602		R602
FTXR	real	1	fraction	/FINNAT/	60	FINANC, R602
FUELC	real	1/30	$	//	42	FINANC, R602
FUELDO	real	1/30	$	//	42	FINANC, R602
FUELN	real	1/30	$	//	42	FINANC, R602
FUELNG	real	1/30	$	//	42	FINANC, R602
FUELO	real	1/30	$	//	42	FINANC, R602
FUELRO	real	1/30	$	//	42	FINANC, R602
GENET	real	1	MWHR	//	15	FINANC
GRSPE	real	1	$	/FINSTA/	52	FINANC
GRSSPE	real	30	$	//	64	FINANC(S), R602
GRSSRB	real	1/30	$	FINANC, R602		FINANC(S), R602
GRTX	real	30	$	R602		R602
GRTXAL	real	1/30	$	FINANC, R602		FINANC(S), R602
GRTXR	real	1	fraction	/FINSTA/	61	FINANC, R602
H	real	30	fraction	FINANC		FINANC
HADF	real	1	fraction	/FINSTA/	65	FINANC, DEPREC
IAGEBK	integer	1	year	FINANC		FINANC
IBRIDG	integer	9		FINANC		FINANC

Table C8-4 (con't)

Variable	Type	Dimension	Unit	Storage Location	Data Group Accessed From[a]	Accessed By
ICONST	integer	1		FINANC		FINANC
ICUM	real	1		/FINSTA/	61	FINANC
ICWIP	real	1		/FINSTA/	61	FINANC
IDGRP	integer	1		FINANC		FINANC
IENTRY	integer	1		FINANC		FINANC
IGRP	integer	1		FINANC		FINANC
IPRYR	integer	30	year	R602		R602
IRATE	real	1		/FINSTA/	61	FINANC
ISTATE	integer	1		argument		FINANC
ITC	real	1/30	$	FINANC, R602		FINANC(S), R602
ITRACE	integer	1		argument		FINANC
ITXP	real	30	$	R602		R602
ITXR	real	30	$	R602		R602
IYEAR	integer	1	year	argument		FINANC, DEPREC
IYEARR	integer	50		/CURREP/		R602
IYEARS	integer	1	year	/REPVAR/		R602
IYR	integer	1		FINANC, R602		FINANC, R602
JYR	integer	1		R602		R602
KKO	real	1		DEPREC		DEPREC
KURREP	real	1		argument		R601, R602
KURYR	integer	1		argument		R601, R602
LAST	integer	1		R602		R602
LASTOD	logical	1	binary	R602		R602
LASTYR	logical	1	binary	argument		R601, R602
LIACAO	real	1/30	$	/FINSTA/	65	FINANC, R602(S)
LIATOT	real	30	$	R602		R602
LIFN	real	1	years	argument		FINANC(S), DEPREC
LIFT	real	1	years	argument		FINANC(S), DEPREC
LITC	real	1	years	/FINSTA/	61	FINANC
LN	real	7	years	/FINNAT/	60	FINANC
LSTATE	integer	50		/SCENAR/		FINANC, R601, R602

Table C8-4 (con't)

Variable	Type	Dimension	Unit	Storage Location	Data Group Accessed From[a]	Accessed By
LSTYR	integer	1		R602		R602
LT	real	7	year	/FINMAT/	60	FINANC
LTDEXP	real	30	$	R602		R602
LTDTOT	real	30	$	R602		R602
LTN	integer	1	year	/FINMAT/	60	FINANC
MAX	integer	1		R602		R602
NETINC	real	30	$	R602		R602
NETPE	real	30	$	R602		R602
NETPLE	real	1	$	/FINSTA/	62	FINANC
NORMFT	real	1		/FINSTA/	61	FINANC, DEPREC
NSCHED	integer	1		FINANC		FINANC
NWCEQ	real	1/30	$	/FINSTA/	65	FINANC, R602
NWDT	real	1/30	$	/FINSTA/	65	FINANC, R602
NWPEQ	real	1/30	$	/FINSTA/	65	FINANC, R602
NXTYR	integer	1		FINANC, R602		FINANC, R602
NYEAR	integer	1	year	/SCENAR/		FINANC, DEPREC, R601, R602
NYEARS	integer	1	year	R602		R602
N2PRNT	integer	1		R602		R602
OASS	real	1	$	FINANC		FINANC
OLDCEQ	real	1/30	$	/FINSTA/	65	FINANC, R602
OLDPEQ	real	1/30	$	/FINSTA/	65	FINANC, R602
OLDT	real	1/30	$	/FINSTA/	65	FINANC, R602
OPEXPO	real	1/30	$	FINANC, R602		FINANC(S), R602
OPREVE	real	1/30	$	//	15	FINANC, R602
OPRXO	real	1/30	$	//	42	FINANC, R602
OPRXPC	real	1/30	$	//	42	FINANC, R602
OPRX1	real	1/30	$	//	42	FINANC, R602
OTHASS	real	30	$	//	64	FINANC, R602
OTHINC	real	30	$	R602		R602
PDIV	real	30	$	R602		R602
PELTOT	real	30	$	R602		R602

Table C8-4 (con't)

Variable	Type	Dimension	Unit	Storage Location	Data Group Accessed From[a]	Accessed By
PEQPC	real	1	fraction	/FINSTA/	61	FINANC, R602
PEQTOT	real	30	$	R602		R602
PP	real	1/30	$	//	15	FINANC, R602
PPFRC	real	1	fraction	//	63	FINANC(S)
PRET	real	1	fraction	/FINSTA/	62	FINANC, R602
PROF1	real	30	fraction	R602		R602
PROF2	real	30	fraction	R602		R602
PROF3	real	30	fraction	R602		R602
PROF4	real	30	fraction	R602		R602
PTQFC	real	1	fraction	//	63	FINANC(S)
PTQFDO	real	1	fraction	//	63	FINANC(S)
PTQFN	real	1	fraction	//	63	FINANC(S)
PTQFNG	real	1	fraction	//	63	FINANC(S)
PTQFO	real	1	fraction	//	63	FINANC(S)
PTQFRO	real	1	fraction	//	63	FINANC(S)
PTQK	real	1	fraction	//	63	FINANC(S)
PTQL	real	1	fraction	//	63	FINANC(S)
PTX	real	1/30	$	FINANC		FINANC(S), R602
PTXR	real	1	fraction	/FINSTA/	61	FINANC
RADCD	real	1	fraction	FINANC		FINANC
RADCE	real	1	fraction	FINANC		FINANC
RBADJ	real	1/30	$	FINANC, R602		FINANC(S), R602
RBDP	real	1/30	$	FINANC, R602		FINANC(S), R602
RBS	real	1	$	argument		FINANC(S), DEPREC
RC	real	1/30	$	FINANC, R602		FINANC(S), R602
RD	real	1/30	$	FINANC, R602		FINANC(S), R602
REGDPE	real	30	$	//	64	FINANC
REGTC	real	1	$	/FINSTA/	61	FINANC
RETBEG	real	30	$	R602		R602
RETERN	real	1/30	$	/FINSTA/	65	FINANC, R602
RETPCT	real	1/30	fraction	R602		R602

Table C8-4 (con't)

Variable	Type	Dimension	Unit	Storage Location	Data Group Accessed From[a]	Accessed By
RETRO	real	12		FINANC		FINANC
REVRQ	real	1/30	$	FINANC		FINANC(S), R602
RGD	real	1	$	DEPREC		DEPREC
RGDF	real	1	$	DEPREC		DEPREC
RGDP	real	35	$	argument		FINANC, DEPREC(S)
RINF	real	1	fraction	/SCENAR/		FINANC
RINFF	real	1	fraction	FINANC		FINANC
RINT	real	1	fraction	/FINSTA/	62	FINANC, R602
ROE	real	1	fraction	FINANC		FINANC
RP	real	1/30	$	FINANC, R602		FINANC(S), R602
RVQ	real	1	$	//	63	FINANC(S)
S	real	1	year	FINANC		FINANC
SDEDS	real	30	$	R602		R602
SITX	real	30	$	R602		R602
SOURCD	real	30	$	R602		R602
SSOTX	real	1/30	$	FINANC		FINANC(S), R602
SSPC	real	1	fraction	/FINNAT/	60	FINANC
STI	real	30	$	R602		R602
STXR	real	1	fraction	/FINSTA/	61	FINANC, R602
SUM	logical	1	binary	argument		R601
SUMM	real	1	$	FINANC		FINANC
SUMRT	real	1	$	R602		R602
SUMYR	logical	1	binary	argument		R602
TBASE	real	30	$	//	64	FINANC
TBSPC	real	1	fraction	/FINSTA/	61	FINANC
TCADJ	real	1	$	argument		FINANC(S), DEPREC
TCTRN	real	30	$	//	64	FINANC(S), DEPREC
TDCWIP	real	1	$	FINANC		FINANC
TDVEST	real	1	$	FINANC		FINANC
TF	real	1/30	$	FINANC, R602		FINANC(S), R602
TOTASS	real	1	$	/FINSTA/	62	FINANC

Table C8-1 (con't)

Variable	Type	Dimension	Unit	Storage Location	Data Group Accessed From[a]	Accessed By
TOTINT	real	30	$	R602		R602
TOTITC	real	1	$	FINANC		FINANC
TOTRBS	real	1	$	FINANC		FINANC
TOTTC	real	1	$	/FINSTA/	61	FINANC
TS	real	1/30	$	FINANC, R602		FINANC(S), R602
TXD	real	1	$	DEPREC		DEPREC
TXDEPR	real	30	$	//	64	FINANC(S), R602
TXDP	real	35	$	argument		FINANC, DEPREC(S)
VAL	real	805		/REPVAR/		R601, R602
VEST	real	1	$	FINANC		FINANC
WCAP	real	30	$	R602		R602
ZITC	real	1	$	FINANC		FINANC
ZITCR	real	30	fraction	/FINNAT/	60	FINANC

[a] See Reference 2 for descriptions of data groups.

[b] (S) means variable is initialized in this subroutine.

[c] // denotes location in blank common.

REFERENCES

1. James J. Stukel. "**Advanced Utility Simulation Model, Analytical Documentation, State Level Model (Version 1.0).**" U.S. Environmental Protection Agency. EPA-600/8-88-071a. January 1989.

2. Caroline J. Badger and Howard Ojalvo. "**Advanced Utility Simulation Model, Documentation of System Design, State Level Model (Version 1.0).**" U.S. Environmental Protection Agency. EPA-600/8-88-071c (NTIS PB89-101208). August 1988.

3. Caroline J. Badger and William H. May. "**Advanced Utility Simulation Model, Model Operations (Version 1.0).**" U.S. Environmental Protection Agency. EPA-600/8-88-071e (NTIS PB89-118749). October 1988.

C9. THE REPORT WRITER

by
Howard Ojalvo

Universities Research Group on Energy
University of Illinois at Urbana-Champaign

9.1 Overview

The process of generating reports from the Advanced Utility Simulation Model (AUSM) involves four distinct phases: (1) dumping raw data from AUSM, (2) sorting the dump file, (3) specifying report options and (4) writing reports. Figure C9-1 depicts the general flow of this process. Phases 1,2 and 4 are discussed in this chapter, while details of REPGEN, the report specification utility program, are provided in Chapter D11.

9.1.1 Generating Report Data

All AUSM report data are written in binary form to unit 10, creating a master file called DUMP. Each module that contributes to a specific report writes a single record at a designated interval. The interval is determined by the type of report, as follows:

Report Type	**Record Frequency**
National input summary	Once, during first call to module
State input summary	First module call for each state
State-yearly results	One record per module call

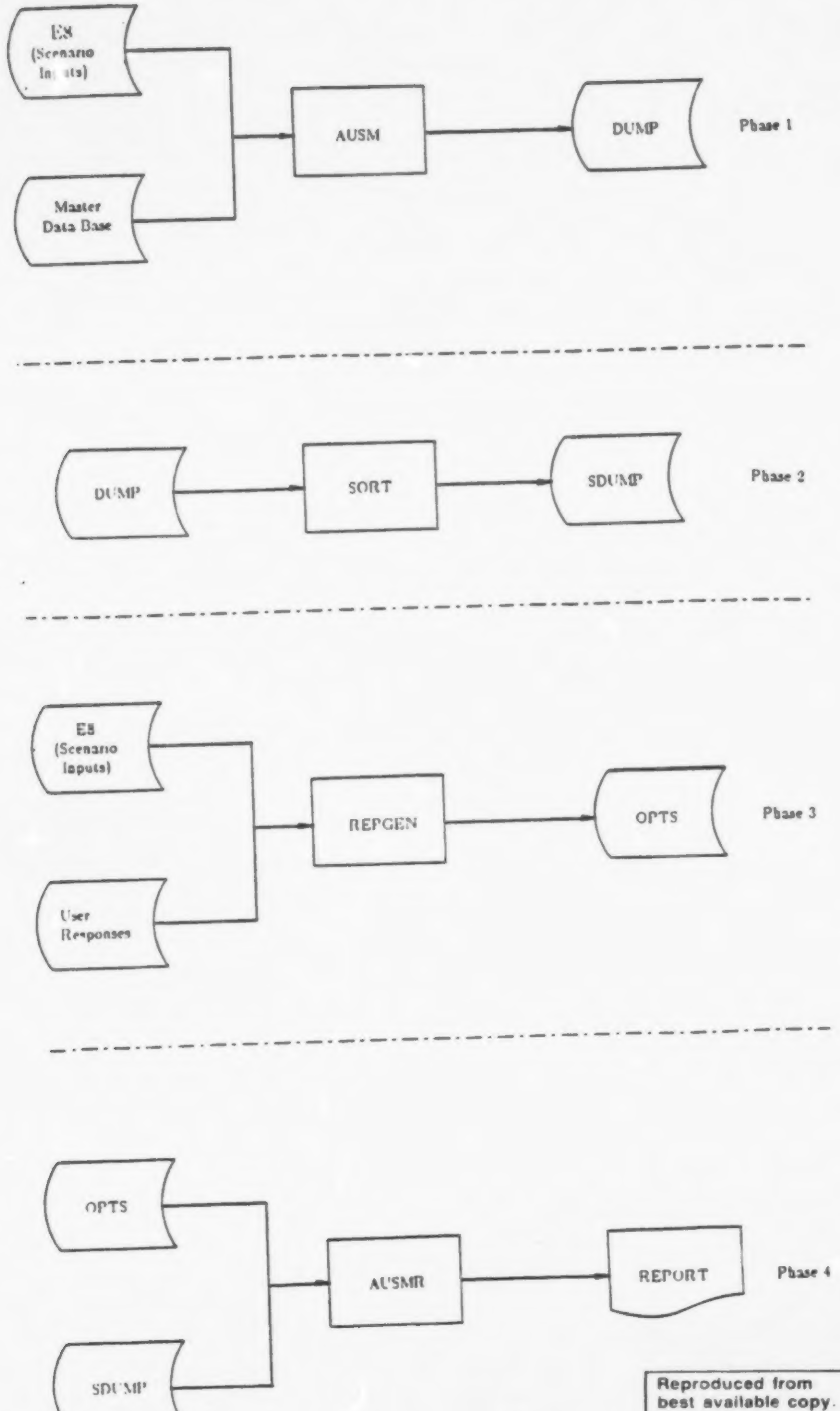
The FORTRAN WRITE statement used by all modules is:

```
WRITE(10) IR,ID,INDEX,ISTATE,IYEAR,NVAL,A1,A2,...,A-NVAL
```

where IRID = report identifier

INDEX = report subindex

Figure C9-1
AUSM REPORT GENERATION PHASES



Reproduced from best available copy.

IYEAR = year

NVAL = number of values being passed

and A1...A-NVAL are the floating point reporting values.

Each module is assigned a range of report identifiers (IRID):

Module	*IRID*
Control Program	000-099
Demand	100-199
Plan	200-299
Comply	300-399
Dispatch	400-499
Impact	500-599
Finance	600-699

Reports requiring data from more than one module will have either an IRID in the range 700-799 or one that specifies the principal module. Such records generated by different modules are distinguished by unique INDEX parameters.

Report identifiers ending in 00 specify national input summary reports; those ending in 01 specify state input summary reports. All others specify state yearly results. Upon completion of an AUSM run, DUMP contains exactly one record for each national input summary report and one record per state for each state input summary report.

9.1.2 Sorting Data

The report data file (DUMP) is sorted by the following keys, which are listed in order of precedence:

–Report identifier

–State code

–Year

–Report subindex

The resulting file is designated SDUMP. A local utility is used to sort data.

9.1.3 Report Specification

REPGEN is a user-interactive program. The user may select the reports to be generated, the reporting years for each report selected, and the states for which each report selected is to be generated.

REPGEN reads the following information from the AUSM scenario file:

–Scenario title

–Date on which AUSM was run

–Number of states in scenario and state list

–First year of simulation and length of simulation.

REPGEN combines the user-selected options with scenario-specific information to create a single option file, OPTS, which is input to the report writing program, AUSMR.

9.1.4 Report Writing

Based on the sorted report data file and the user-specified options file produced by REPGEN (see Chapter D11), AUSMR produces a single output file, which is named REPORT. Individual reports within REPORT are ordered first by ascending report identifier numbers and second by FIPS state code. REPORT begins with a title page.

Descriptive headers are printed at the beginning of individual state reports.

Individual report-writing subroutines are called to process data provided for each selected report. For each state selected, one or more records are read for each year of the simulation. The subroutines perform calculations and accumulate totals as required.

Information is written to the REPORT file only for those years and states requested by the user. Depending on design specifications, a summary may be written for each state report.

9.1.5 Report Generation Files

Besides the DUMP and SDUMP files defined in sections 9.1.1 and 9.1.2, two other files are used in AUSM report generation: E8, the scenario input file, and OPTS, the report option file. REPGEN reads the initial section of E8 and writes it to OPTS. REPGEN also writes additional lines to OPTS to specify report option parameters. The data that comprise the initial sections of both E8 and OPTS are specified as follows:

Record Number	*Format*	*Description*
1-2	(20A4/20A4)	Scenario title
3	2A4	Date AUSM run
4	I2	Number of states
5	50I2	State list (FIPS codes)
6	I4	First simulation year (Julian)
7	I2	Number of years
8	I2	Number of reports (NREPT)

The next NREPT lines are specified as follows:

8 + i	I3,I1,16A4	Report ID, report subindex, report title of the ith report

Report specifications that appear in lines 9 to NREPT+8 occur in ascending order by report identification number.

The second section of OPTS consists of two records per report, also in ascending order by report identification number:

Record Number	*Format*	*Description*
1	50I2	List of states included in the ith report
2	50I1	Summary years for the ith report

9.2 AUSMR: The Report Writing Program

9.2.1 Overview

AUSMR produces reports based on the sorted data dump (SDUMP) generated from an AUSM run. The program consists of two distinct sets of code, a control program and a series of report-writing subroutines.

The control program is responsible for the overall flow of an AUSMR run. The nine subroutines in the program perform the following tasks: (1) write all report headers, (2) determine user-directed reporting specifications by reading the OPTS file, (3) read and verify all data from SDUMP, and (4) call report-writing subroutines to process individual data records and to write reports.

There is one report-writing subroutine for every possible AUSMR report. A specific routine is called in succession to compose a report as the pertinent data are read from SDUMP. As a result of arguments passed to the routines by the control problem, each routine recognizes when to bypass a state, when to print a descriptive header for a new report, and whether summary results should be written in the current year.

Only minimal modifications are required in the AUSMR control program to add new reports. Specific criteria required for the successful integration of new reporting routines into the AUSMR are described in Sections 9.2.2.8 and 9.2.2.9.

9.2.2 Subroutine Summaries

Table C9-1 provides a brief summary of AUSMR control subprograms. These subprograms are summarized in Sections 9.2.2.1 through 9.2.2.10.

9.2.2.1 Program AUSMR

Calls:	MORSTA, ROUTER.
Task:	Supervisory routine for the AUSM report-writing program; guides overall report generation according to AUSM scenario parameters and reporting options read from OPTS.

Table C9-1

SYNOPSES OF AUSMR CONTROL PROGRAM SUBPROGRAMS

Subprogram	Synopsis	Called By
AUSMR	Supervisory routine for the AUSM report-writing program; guides overall report generation according to AUSM scenario parameters and reporting options	
CHECK	Data verification routine	ROUTER
GETSTA	Looks up state name associated with FIPS code	HEADRS
HEADRS	Prints page headers and title page	Report-writing routines
LOGO	Prints AUSM logo for title page	HEADRS
MORSTA	Function; determines whether a specific report has been written for all user-selected states	AUSMR
REPYR	Function; determines whether the year in progress has been selected as a summary year for current state-report	ROUTER
ROUTER	Reads report data and routes program control to a report-writing routine	AUSMR
Report-writing routines	Process data provided for a specific report and write AUSM results to the report file	ROUTER

Method: Reads lines 1-8 of the OPTS file to discern the contents of the sorted data dump file (SDUMP). In particular, the list of simulated states is read directly into array LSTATE. Variables NREPT and NYEAR store, respectively, the number of reports and the number of years in the simulation. The identifier of each report is also read from OPTS.

Each report is processed successively. As a report is processed, two lines are read from the OPTS file which specify the list of states (ISTATR) which the user has chosen to appear in the current report and the selected list of summary years (IYEARR). The function MORSTA is next called to determine if all of the states present in ISTATR have been processed and to skip any states not selected. If all states have been completed, processing of the next report begins; otherwise, subroutine ROUTER is called for each year in the simulation to read yearly data from the SDUMP and to route program control to the appropriate report-writing routine.

9.2.2.2 Subroutine CHECK

Called by: ROUTER.

Arguments:
IDS - Report identifier read from data file.
IDSUBS - Report subindex read from data file.
ISTATS - State identifier read from data file.
IYEARS - Year read from data file.
IDR - Report identifier expected.
IDSUBR - Report subindex expected.
ISR - State identifier expected.
IYR - Year expected.

Task: Logical function; returns the value "true" if values read from OPTS for the report identifer, subindex, state code, and year match those expected. Otherwise, "false" is returned.

9.2.2.3 Subroutine GETSTA

Called by: HEADRS.

Arguments: IFIPS - State FIPS code.
NAME - State name.

Task: Looks up state name associated with FIPS state code.

9.2.2.4 Subroutine HEADRS

Calls: GETSTA, LOGO.

Called by: Report-writing routines.

Arguments: KURREP - Current report index.
NUMPAG - Page number.

Task: Prints standard heading for each report page. Prints a title page on first call.

9.2.2.5 Subroutine LOGO

Called by: HEADRS.

Task: Prints AUSM logo for report title page.

9.2.2.6 Function MORSTA

Called by: AUSMR.

Argument: KURREP - Current report.

Task: Logical function; determines whether all of the states selected by the user for reporting have been processed. If data are present in SDUMP for states that have not been selected for a particular report, reads past the associated records.

Method: A dual set of pointers, IPT and LSTAPT, is maintained to index, respectively, the list of states for which data are present (LSTATE) and the list of states selected for the current report (ISTATR). MORSTA is called once for each state per report; ISTATR is incremented by one in order to access the current state code. If this state code is not found in ISTATR, then SDUMP is repositioned past the records corresponding to this state and the value of MORSTA is set to "false."

9.2.2.7 Function REPYR

Called by: ROUTER.

Argument: KURYR - Current year index.

Task: Logical function; determines whether the year index KURYR is among those selected as a summary year for the current state report.

Method: A pointer IPT is maintained to index the list of user-selected summary years (IYEARR). If the value of KURYR is found in IYEARR, then REPYR is set to "true."

9.2.2.8 Subroutine ROUTER

Called by: AUSMR.

Calls: All reporting routines, CHECK, REPYR.

Arguments: KURYR - Current year index.
KURREP - Current report index.

Task: Reads a single line from the SDUMP file and routes control flow to the proper report-writing routine. Function CHECK is called to determine whether the expected report identifier, state code, and subindex match those read.

Maintenance: ROUTER is the only subroutine in the AUSMR control program that requires any modifications to insert new reports. To add a report, a single line is inserted in the section of code corresponding to the appropriate AUSM module. For example, to add a report numbered 250, ROUTER would be modified by insertion of

```
IF(IDR(KURREP).EQ.250)CALL R250(SUM,FRSTYR,LASTYR,KURYR,KURREP)
```

within the section of code preceeded by the comment

```
C.........PLAN REPORTS.....................
```

Other than the designation "250," which applies to a specific capacity planning module report, this example illustrates the precise appearance of all new report-writing routine calls.

9.2.2.9 Report-Writing Subroutines

These subroutines are designated Rxxx, where xxx is a numeric report identifier.

Calls: HEADRS.

Called by: ROUTER.

Arguments:

SUM - Logical; equals "true" if the current year is a user-specified summary year.

FRSTYR - Logical; equals "true" if the current year is the first year for a new state-report.

LASTYR - Logical; equals "true" if the current year is the last year for a state-report.

KURYR - Current year index.

KURREP - Current report index.

Task: A report-writing subroutine processes data provided for a specified report and writes AUSM results to the REPORT file. Except for input summary reports, individual reports encompass a single state over the full AUSM simulation period. There are two types of input summary reports: (1) national summaries, which are generated once per AUSM simulation, and (2) state summaries, which are generated once per state.

Method: Except as noted above, a routine is called in succession once for each simulation year. Data read from SDUMP are passed to the routine in the common block /CURREP/. The subroutine performs necessary calculations and accumulates totals as required.

The argument SUM specifies whether the user has designated the current year for summary results. A specific report interprets SUM according to individual reporting requirements. For example, SUM may flag that accumulated totals are to be printed, or it may be completed ignored.

Maintenance: A complete report-writing routine must be devised in order to add a new AUSM report. Each such subroutine begins as follows:

```
      SUBROUTINE R–(SUM,FRSTYR,LASTYR,KURYR,KURREP)
C
C
C
      COMMON /REPVAR/ IDS,IDSUBS,ISTATE,IYEAR,NVAL,VAL(805)
      COMMON /CURREP/ ISTATR(50),IYEARR(50),ISTAPT
      COMMON /SCENAR/ NSTATE,NYEAR,NYEAR1,LSTATE(50),XDATE(2),
   + TITLE(40),NREPT,IDR(25),INDXS(25),DESCR(16,25)
      LOGICAL SUM,FRSTYR,LASTYR
```

Report-writing routines effect the beginning of a new page by calling subroutine HEADRS, i.e.,

```
CALL HEADRS (KURREP,n)
```

The argument 'n' specifies the page number. Each state-specific report begins on page 1.

Useful data are passed from the control program to a report-writing routine via the following arguments and common variables:

Variable	*Common Block*	*Description*
FRSTYR (argument)		Logical; equals true if the current years is the first year for a new state report
IDSUBS	/REPVAR/	Subindex
ISTATS	/REPVAR/	State FIPS code
IYEARS	/REPVAR/	Current year (Julian)
LASTYR (argument)		Logical; equals true if the current year is the last year for a state report
NVALS	/REPVAR/	Number of data values passed
SUM (argument)		Logical; equals true if the current year is a user-specified summary year
VAL	/REPVAR/	Data values

9.2.3 Subprogram Flowcharts

The principal report-writing subprograms are flowcharted in Figure C9-2 (AUSMR), Figure C9-3 (MORSTA), and Figure C9-4 (ROUTER).

9.2.4 Variable Definitions

The control program variables in AUSMR are summarized in Table C9-2.

Figure C9-2
PROGRAM AUSMR

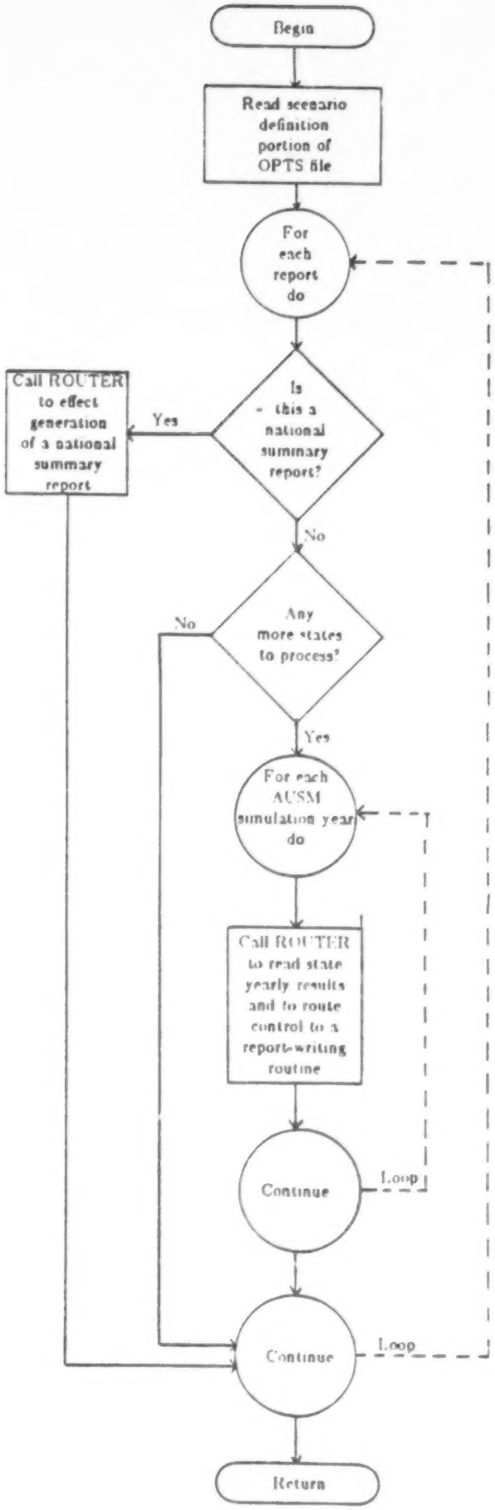

Begin
Read scenario definition portion of OPTS file
For each report do
Is this a national summary report?
Yes
Call ROUTER to effect generation of a national summary report
No
Any more states to process?
No
Yes
For each AUSM simulation year do
Call ROUTER to read state yearly results and to route control to a report-writing routine
Continue
Loop
Continue
Loop
Return

Figure C9-3
FUNCTION MORSTA

Key
LSTATE: List of states in AUSM scenario
NYEAR: Number of years in AUSM scenario

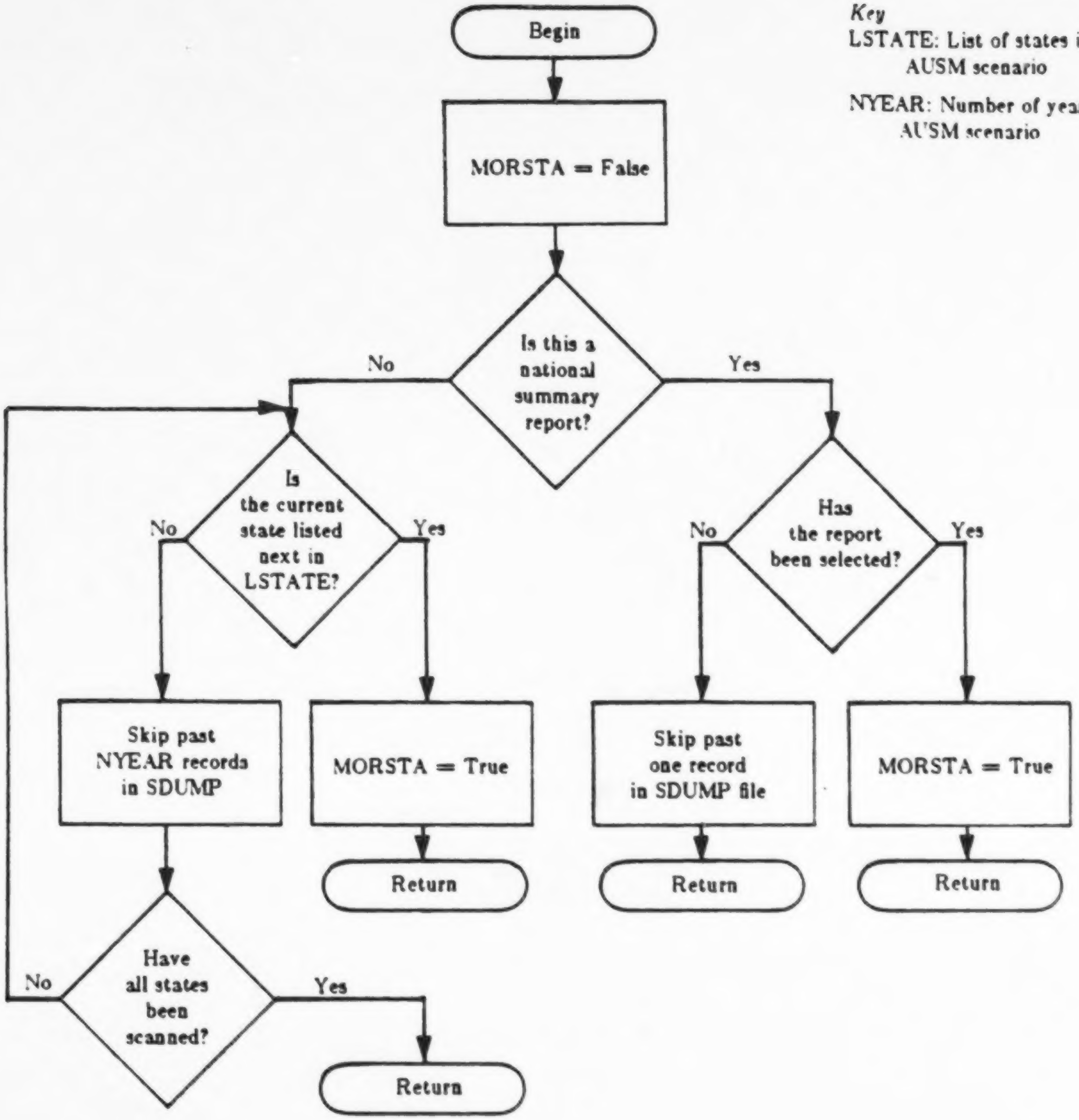
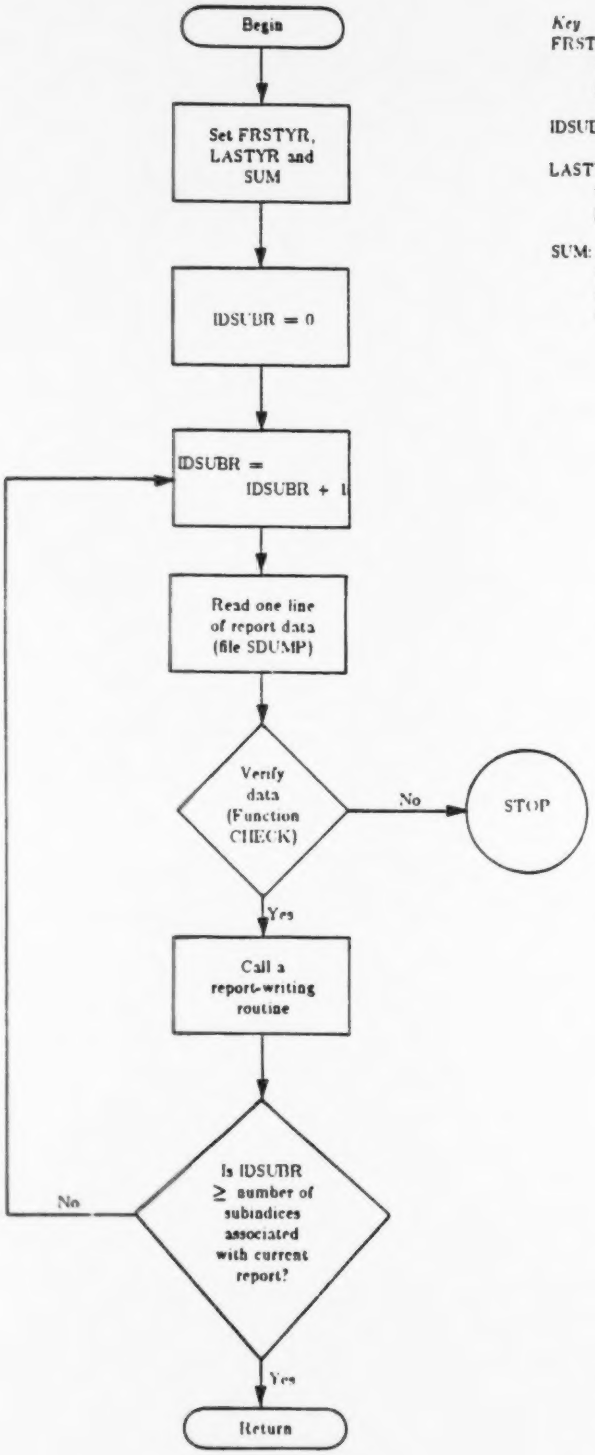

Begin
MORSTA = False
Is this a national summary report?
No
Yes
Is the current state listed next in LSTATE?
No
Yes
Has the report been selected?
No
Yes
Skip past NYEAR records in SDUMP
MORSTA = True
Skip past one record in SDUMP file
MORSTA = True
Return
Return
Return
Have all states been scanned?
No
Yes
Return

Figure C9-4
FUNCTION ROUTER


Begin
Set FRSTYR, LASTYR and SUM
IDSUBR = 0
IDSUBR = IDSUBR + 1
Read one line of report data (file SDUMP)
Verify data (Function CHECK)
No
STOP
Yes
Call a report-writing routine
Is IDSUBR ≥ number of subindices associated with current report?
No
Yes
Return

Key

FRSTYR: Logical variable indicating whether year 1 data is being processed

IDSUBR: Report subindex counter

LASTYR: Logical variable indicating whether last year data is being processed

SUM: Logical variable indicating whether state report summaries shall be carried out in current year

Table C9-2

VARIABLE INFORMATION FOR AUSMR CONTROL PROGRAM

Variable	Dimension	Description	Location	Accessed By
DESCR	16,25	Title/description of all AUSM reports included in scenario	/SCENAR/	AUSMR,HEADRS
FRSTYR		Logical variables indicates whether year 1 data is being processed	argument	ROUTER
IDR		Report identifer read from OPTS file	argument /SCENAR/	AUSMR,CHECK, HEADRS,MORSTA, ROUTER
IDS		Report identifier read from SDUMP file	argument /REPVAR/	HEADRS,ROUTER CHECK
IDSUBR		Report subindex read from OPTS file	argument	CHECK,ROUTER
IDSUBS		Report subindex read from SDUMP file	argument, /REPVAR/	CHECK,ROUTER
IFIPS		State FIPS code	argument	GETSTA,HEADRS
IMODUL		AUSM module identifier		ROUTER
INAME	4	State name (character string)		HEADRS
INDXS	25	Number of subindices per report	/SCENAR/	AUSMR,MORSTA, ROUTER
IPN		Report page number		HEADRS
IPT		Pointer to element in LSTATE		MORSTA
IPT		Pointer to element in IYEARR		REPYR
ISR		State FIPS code	argument	CHECK,ROUTER
ISTAT1	48	Stores state names for look-up		GETSTA
ISTAT2	48	Stores state names for look-up		GETSTA
ISTAT3	48	Stores state names for look-up		GETSTA
ISTAT4	48	Stores state names for look-up		GETSTA

Table C9-2 (contd.)

Variable	Dimension	Description	Location	Accessed By
ISTAT5	32	Stores state names for look-up		GETSTA
ISTATR	50	List of states selected for inclusion in current report	/CURREP/	AUSMR,HEADRS, MORSTA,ROUTER
ISTATS		State read from SDUMP	argument /REPVAR/	CHECK,HEADRS, ROUTER
ISTAPT		Pointer to element in ISTATR	/CURREP/	BLOCK DATA, HEADRS,MORSTA, ROUTER
IYEARR	50	List of indicies of years selected for inclusion in current report	/CURREP/	REPYR,ROUTER
IYEARS		Year index from SDUMP file	argument /REPVAR/	HEADRS,MORSTA
IYR		Current year index	argument	CHECK,ROUTER
KURREP		Current report index	argument	AUSMR,HEADRS, MORSTA,ROUTER
KURYR		Current year index	argument	AUSMR,HEADRS, MORSTA,ROUTER
LASTYR		Logical variable indicates whether last year is being processed	argument	ROUTER
LSTATE	50	List of states in AUSM scenario	/SCENAR/	AUSMR,MORSTA
MULT		Number of SDUMP records per state-year		MORSTA
NAME	4	Name of state (character string)	argument	GETSTA
NREPT		Number of reports in AUSM scenario	/SCENAR/	AUSMR
NREC		Number of records skipped		MORSTA
NSTATE		Number of states in AUSM scenario	/SCENAR/	AUSMR,MORSTA

Table C9-2 (contd.)

Variable	Dimension	Description	Location	Accessed By
NUMPAG		Page number	argument	HEADRS
NVALS		Number of data values read from an SDUMP record	/REPVAR/	ROUTER
NYEAR		Number of years in AUSM scenario	/SCENAR/	AUSMR,MORSTA, ROUTER
NYEAR1		First year in AUSM scenario	/SCENAR/	AUSMR,ROUTER
SUM		Logical variable; indicates whether a state-report summary shall be carried out in current year	argument	ROUTER
TITLE	40	Title of AUSM scenario (character string)	/SCENAR/	AUSMR,HEADRS
TODAY	2	Date of AUSMR run		HEADRS
VAL	805	Data values read from SDUMP file	/REPVAR/	ROUTER
XDATE	2	Date of AUSM run	/SCENAR/	AUSMR,HEADRS

Note: The control program uses the default variable typing implicit in FORTRAN. A variable name that begins with the letter I, J, K, L, M or N implies type integer; any other letter implies type real.

D10. THE SCENARIO SELECTOR

by
William H. May

Universities Research Group on Energy
University of Illinois at Urbana-Champaign

10.1 Introduction

10.1.1 Overview

The Advanced Utility Simulation Model (AUSM) reads directives and parameters defining a scenario run from the external file E8. The file E8 contains general information about the scenario such as a two line title, an execution date, states to be run, simulation period, report identifiers and a descriptive text. It also contains the model parameters that may be altered by the user before an AUSM run. A detailed description of file E8 appears in Chapter C3 of this report, and in Sections 2 and 3 of the AUSM system design document [1]. Figure D10-1 is a "generic" file E8 with default values for all directives and parameters.

10.1.2 SCNGEN

SCNGEN is an interactive program for modifying an existing file E8 (either a file from a previous run or the "generic" file shown in Figure D10-1). SCNGEN reads the existing file E8 and queries the user for modifications grouping the contents into subsets of related items. Every item in a file E8 (except report titles) may be modified by the user. The modified version of file E8 is output to a new file E8.

The main routine of SCNGEN presents a set of instructions to the user, reads the old file E8, then requests instructions to modify or terminate, and write the new file E8. Modification continues at the global level (all general information and global parameters 1-101) or the state-level (state parameters 501-565, (R)NSPS standards, data groups 26, 17 and 19) by calling either subroutine GLOBAL or STATE. The modification routines group subsets of parameters for change and call unique subroutines to modify each set. These lower order routines query the user for specific items to be modified. Figure D10-2 shows a schematic flow of this process.

Each of the modifying subroutines has a similar structure. First a title is printed and the user is prompted for a selection. Valid selections are integers from 0 to n (where n is the number of selections) and 99. The 99 selection initiates a return to the next higher routine. A zero selection always presents the current menu. Figure D10-3 is a schematic representation of the selection process.

Table D10-1 displays the subsets of items from an E8 file with a brief description and indicates which of the modifying routines is called to make the changes. Note that all global parameters are changed by routines beginning with G and that state parameters are changed by those beginning with S.

10.2 Subroutine Summaries

10.2.1 Subroutine BLOCK DATA

Task:	Initalizes all scenario arrays.

10.2.2 Subroutine ENDFLE

Called by:	All routines.		
Arguments:	IHIGH	-	upper range of acceptable value
	LOW	-	lower range of acceptable value
Task:	Handles null input from terminal.		

10.2.3 Subroutine E8IN

Called by:	SCNGEN
Task:	Reads in default E8 scenario file from I/O unit reference 1.

Figure D10-1

DEFAULT SCENARIO DIRECTIVES FILE, E8

```
*** AUSM ***            DEFAULT SCENARIO DIRECTIVES FILE            *** AUSM ***
*** AUSM ***              FOR A SINGLE SAMPLE STATE               *** AUSM ***
00/00/00                               DATE EXECUTED
 1                   1/2-51            NUMBER OF STATES/STATE LIST
01
1980                   52              INITIAL YEAR
 0                     53              NUMBER OF YEARS
34                                     NUMBER OF REPORTS/LIST OF TITLES
  0 1 GLOBAL SCENARIO VARIABLES
  1 1 STATE SCENARIO VARIABLES
102 1 SALES AND GENERATION
103 1 ANNUAL DEMAND FOR ELECTRICITY BY SECTOR
104 1 ANNUAL DEMAND FOR PRIMARY FUELS BY SECTOR
105 1 AVERAGE COST OF SERVICE PER KWH SOLD
106 1 AVERAGE COST OF SERVICE PER KWH GENERATED
107 1 PRICES PAID FOR ELECTRICITY BY SECTOR
108 1 TYPICAL MONTHLY BILLS BY SECTOR
109 1 TYPICAL ANNUAL USE AND COST OF ELECTRICITY BY CUSTOMER
110 1 DEMAND PROJECTIONS
111 1 DEMAND SUMMARY
112 1 ECONOMIC AND DEMOGRAPHIC OUTPUTS
200 1 GLOBAL CPACITY PLANNING INPUTS
201 1 STATE CAPACITY PLANNING INPUTS
205 3 SYSTEM SIZE
210 1 PROJECTED SIZE AND DEMAND
215 1 CAPITAL COSTS FOR TRANSMISSION & DISTRIBUTION
220 1 RESERVE MARGINS
225 1 GENERATING TECHNOLOGY MIX
300 1 EXOGENOUS CONTROL TECHNOLOGY PARAMETERS
301 1 (R)NSPS STANDARDS WITH USER MODIFICATIONS
305 1 SCRUBBED CAPACITY (MW)
410 2 ANNUAL FUEL AND OPERATION COSTS
420 1 GENERATION SUMMARY
505 1 STATE EMISSION SUMMARY
510 1 COAL MOVEMENT - 1000 TONS
515 1 COAL MOVEMENT -  MM  BTU'S
601 1 FINANCIAL ASSUMPTIONS REPORT
602 1 FINANCIAL SUMMARY
700 1 COAL DATA PARAMETERS
703 1 DELIVERED COAL PRICES
705 1 ALTERNATE FUEL PRICES
710 1 CAPITAL EXPENDITURES
 2          NUMBER OF NOTE LINES          UP TO 20 LINES     LONGEST ENDING HERE ==========>
INSERT NOTES THAT ARE TO APPEAR ON THE COVER SHEET OF THE REPORT
UP TO 20 LINES ARE ALLOWED;CHANGE "NUMBER OF NOTES" LINE ABOVE
```

Figure D10-1 (contd.)

```
53  20  23  23 18  4                       NBR OF GLOBAL,STATE,RNSPS,TECH, & DG17,DG19 RECORDS
 **********GLOBAL*******
 .6000E-01            54            INFLATION RATE
      .130            55            INTEREST, NEW DEBT
      .130            56            DESIRED PREFERRED EQUITY RETURN
      .150            57            DESIRED COMMON EQUITY RETURN
                      58
                      59
                      60
       0.0            61            CONSTRUCTION COST ESCALATION RATE, NUCLEAR
       0.0            62            CONSTRUCTION COST ESCALATION RATE, NON-NUCLEAR
       0.0            63            CONSTRUCTION DEFERRAL FRACTION
     1980.            64            FIRST YEAR BASELOAD DEFERRAL ALLOWED
     1980.            65            FIRST YEAR PLANNING ADDITIONS ALLOWED
       0.0            66            MPMS SWITCH
       1.0            67            DISPATCHING METHOD
       1.0            68            COAL DATA SOURCE
       0.0            69            LOCAL COAL SWITCH
       0.0            70            EXOGENOUS CAPACITY PLANNING SWITCH
       0.0            71            LIMITED SO2 OPTIONS PERIOD 1
     9999.            72            YEAR BEGIN LIMITED SO2 COMPLIANCE
       0.0            73            LIMITED SO2 OPTIONS PERIOD 2
     9999.            74            YEAR BEGIN LIMITED SO2 COMPLIANCE
       0.0            75            LIMITED SO2 OPTIONS PERIOD 3
     9999.            76            YEAR BEGIN LIMITED SO2 COMPLIANCE
     1980.            77            YEAR DRY FGD BECOMES AVAILABLE
     1992.            78            YEAR LIMB BECOMES AVAILABLE
       0.0            79            POLLUTION CONTROL MANAGEMENT SWITCH
     9999.            80            SO2 PERMIT MARKET OR SIP ROLLBACK YEAR
       0.0            81            PERSONAL INCOME GROWTH RATE OVER BASE
       0.0            82            POPULATION GROWTH RATE OVER BASE
       0.0            83            EARNINGS GROWTH RATE OVER BASE
       0.0            84            EMPLOYMENT GROWTH RATE OVER BASE
     9999.            85            YEAR BEGIN NON-BASE ECONOMIC GROWTH
     9999.            86            YEAR BEGIN HOLDING ECONOMIC INPUTS CONSTANT
                      87
                      88
                      89
                      90
       0.0            91            OIL PRICE GROWTH RATE OVER BASE
       0.0            92            NATURAL GAS PRICE GROWTH RATE OVER BASE
       0.0            93            NUCLEAR FUEL PRICE GROWTH RATE OVER BASE
     9999.            94            YEAR BEGIN NON-BASE FUEL PRICES
     9999.            95            YEAR BEGIN KEEPING FUEL PRICES CONSTANT
     1.000            96            FUEL PRICE INDICATOR
                      97
                      98
                      99
                     100
       0.0           101            EXOGENOUS DEMAND SWITCH
       0.0           102            EXOGENOUS QUANTITIES SWITCH
     9999.           103            DEMAND RECALIBRATION YEAR
       0.0           104            DEMAND RECALIBRATION QUANTITIES SWITCH
       0.0           105            DEMAND NET POWER TRANSFER SWITCH
     1990.           106            END YEAR FOR COAL CONTRACTS
```

Figure D10-1 (contd.)

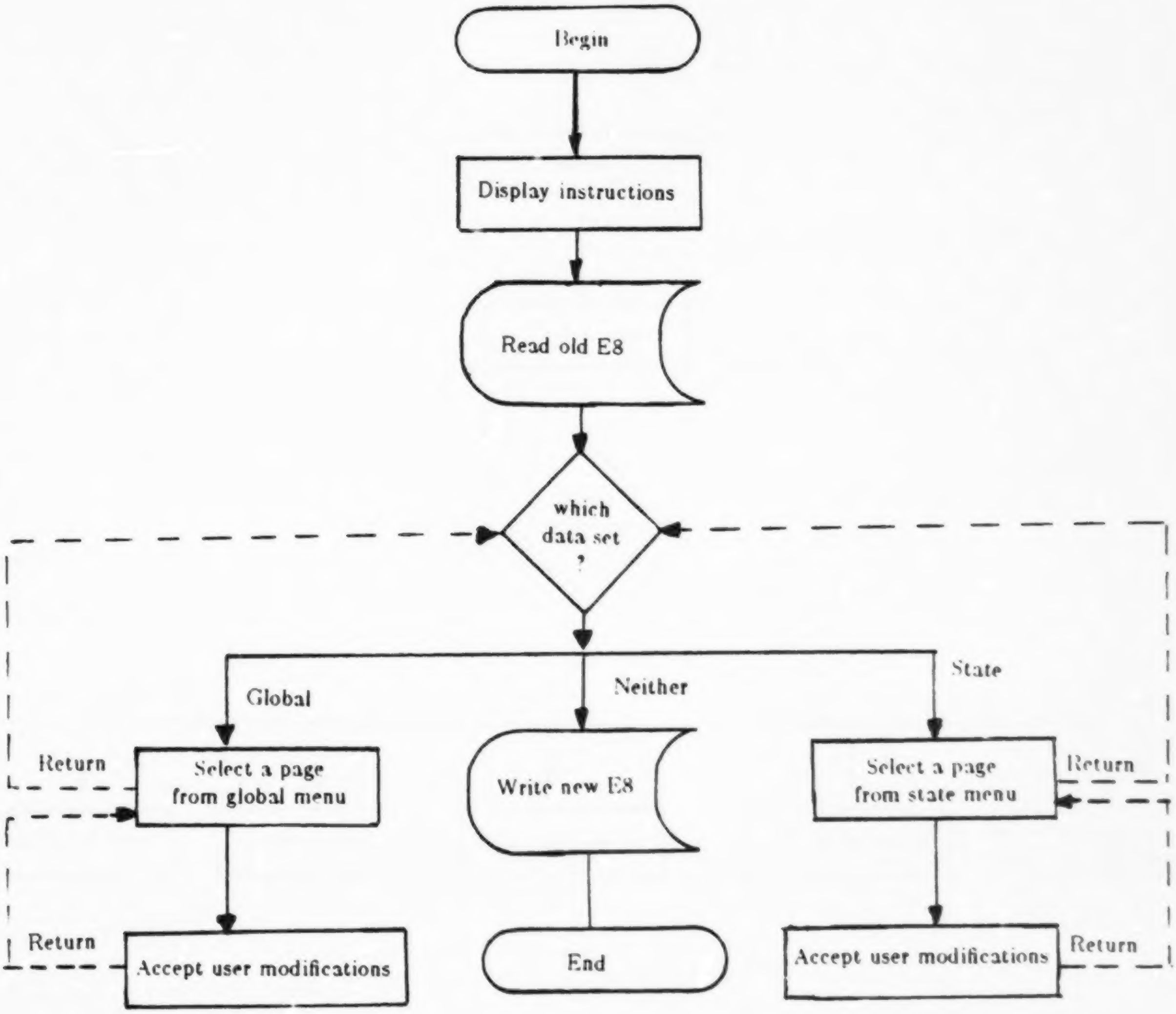
```
**********STATE*******
   01.00          500          ALABAMA
   5000.          501       LAND USE COST $/ACRE
   7.480          502       REAGENT COST WET FGD
   57.00          503       REAGENT COST DRY FGD
   7.480          504       REAGENT COST LIMB
     0.0          510       SULFUR RSD EXEMPTION OLD UNITS
   3.000          511       SULFUR RSD EXEMPTION NEW UNITS
   3.000          512       SULFUR RSD AVERAGING TIME OLD UNITS
   2.000          513       SULFUR RSD AVERATING TIME NEW UNITS
.2000E+21         528       SO2 EMISSION/COST LIMIT
.2000E+21         529       NOX EMISSION/COST LIMIT
.2000E+21         530       TSP EMISSION/COST LIMIT
     0.0          540       SO2 PERMIT ALLOCATION
     0.0          541       FRACTION SO2 ROLLBACK
   770.0          560       CONSTRUCTION COST COAL STEAM
   1050.          561       CONSTRUCTION COST LIGHT WATER REACTOR
   200.0          562       OIL TO COAL CONSTRUCTION COST
   1980.          563       NUCLEAR MORATORIUM END YEAR
     0.0          564       NUCLEAR CONSTRUCTION FRACTION
                  565
     0.0           R        SO2 EMISSION COAL CEILING A
     0.0           N        SO2 EMISSION COAL CEILING B
     0.0           S        CEILING A
     0.0           P        CEILING B
     0.0           S        COMPLIANCE YEAR
     0.0                    SO2 EMISSION OIL CEILING C
     0.0           S        SO2 EMISSION OIL NO CEILING
     0.0           T        CEILING C
     0.0           A        COMPLIANCE YEAR
     0.0           N        SO2 EMISSION COAL GASIFICATION CEILING D
     0.0           D        SO2 EMISSION COAL GASIFICATION NO CEILING
     0.0           A        CEILING D
     0.0           R        COMPLIANCE YEAR
     0.0           D        TSP EMISSION NEW UNITS
     0.0           S        COMPLIANCE YEAR
     0.0                    NOX EMISSION BITUMS
     0.0           F        COMPLIANCE YEAR
     0.0           O        NOX EMISSION SUB-BITUMS
     0.0           R        COMPLIANCE YEAR
     0.0                    NOX EMISSION OIL
     0.0           G        COMPLIANCE YEAR
     0.0           3        NOX EMISSION GAS
     0.0           1        COMPLIANCE YEAR
```

Figure D10-1 (contd.)

```
    .05                         FRACTION BUILD MIX TECH  1
    .05                         FRACTION BUILD MIX TECH  2
    0.0                         FRACTION BUILD MIX TECH  3
    0.0                         FRACTION BUILD MIX TECH  4
    0.0                         FRACTION BUILD MIX TECH  5
    0.0                         FRACTION BUILD MIX TECH  6
    0.0                         FRACTION BUILD MIX TECH  7
    0.0                         FRACTION BUILD MIX TECH  8
    0.0                         FRACTION BUILD MIX TECH  9
    0.0                         FRACTION BUILD MIX TECH 10
    0.0                         FRACTION BUILD MIX TECH 11
    0.0                         FRACTION BUILD MIX TECH 12
    0.0                         FRACTION BUILD MIX TECH 13
    0.0                         FRACTION BUILD MIX TECH 14
    .90                         FRACTION BUILD MIX TECH 15
    0.0                         FRACTION BUILD MIX TECH 16
    0.0                         FRACTION BUILD MIX TECH 17
    0.0                         FRACTION BUILD MIX TECH 18
    0.0                         FRACTION BUILD MIX TECH 19
    0.0                         FRACTION BUILD MIX TECH 20
    0.0                         FRACTION BUILD MIX TECH 21
    0.0                         FRACTION BUILD MIX TECH 22
    0.0                         FRACTION BUILD MIX TECH 23
0.0   0.0   0.0   0.0   0.0     END YEARS EXOGENOUS DEMAND TIME PERIODS
0.0   0.0   0.0   0.0           DEMAND GROWTH RATES PERIOD 1
0.0   0.0   0.0   0.0           DEMAND GROWTH RATES PERIOD 2
0.0   0.0   0.0   0.0           DEMAND GROWTH RATES PERIOD 3
0.0   0.0   0.0   0.0           DEMAND GROWTH RATES PERIOD 4
0.0   0.0   0.0   0.0           DEMAND GROWTH RATES PERIOD 5
 0.0     0.0     0.0     0.0     0.0 QUANT TRANSF POWER YEARS  1- 5
 0.0     0.0     0.0     0.0     0.0 QUANT TRANSF POWER YEARS  6-10
 0.0     0.0     0.0     0.0     0.0 QUANT TRANSF POWER YEARS 11-15
 0.0     0.0     0.0     0.0     0.0 QUANT TRANSF POWER YEARS 16-20
 0.0     0.0     0.0     0.0     0.0 QUANT TRANSF POWER YEARS 21-25
 0.0     0.0     0.0     0.0     0.0 QUANT TRANSF POWER YEARS 26-30
0.00    0.00    0.00    0.00    0.00 EXPECTED COST OF TRANSF YEARS  1- 5
0.00    0.00    0.00    0.00    0.00 EXPECTED COST OF TRANSF YEARS  6-10
0.00    0.00    0.00    0.00    0.00 EXPECTED COST OF TRANSF YEARS 11-15
0.00    0.00    0.00    0.00    0.00 EXPECTED COST OF TRANSF YEARS 16-20
0.00    0.00    0.00    0.00    0.00 EXPECTED COST OF TRANSF YEARS 21-25
0.00    0.00    0.00    0.00    0.00 EXPECTED COST OF TRANSF YEARS 26-30
    0.0                         TOTAL SALES-ELECTRIC RECALB YEAR
    0.0                         TOTAL SALES-GAS RECALB YEAR
    0.0                         TOTAL SALES-OIL RECALB YEAR
    0.0                         TOTAL SALES-COAL RECALB YEAR
```

Figure D10-2

SCNGEN FLOWCHART


Begin
Display instructions
Read old E8
which data set ?
Global
Neither
State
Return
Select a page from global menu
Write new E8
Select a page from state menu
Return
Return
Accept user modifications
End
Accept user modifications
Return

Reproduced from best available copy.

Figure D10-3
FLOWCHART FOR A SCNGEN MENU PAGE

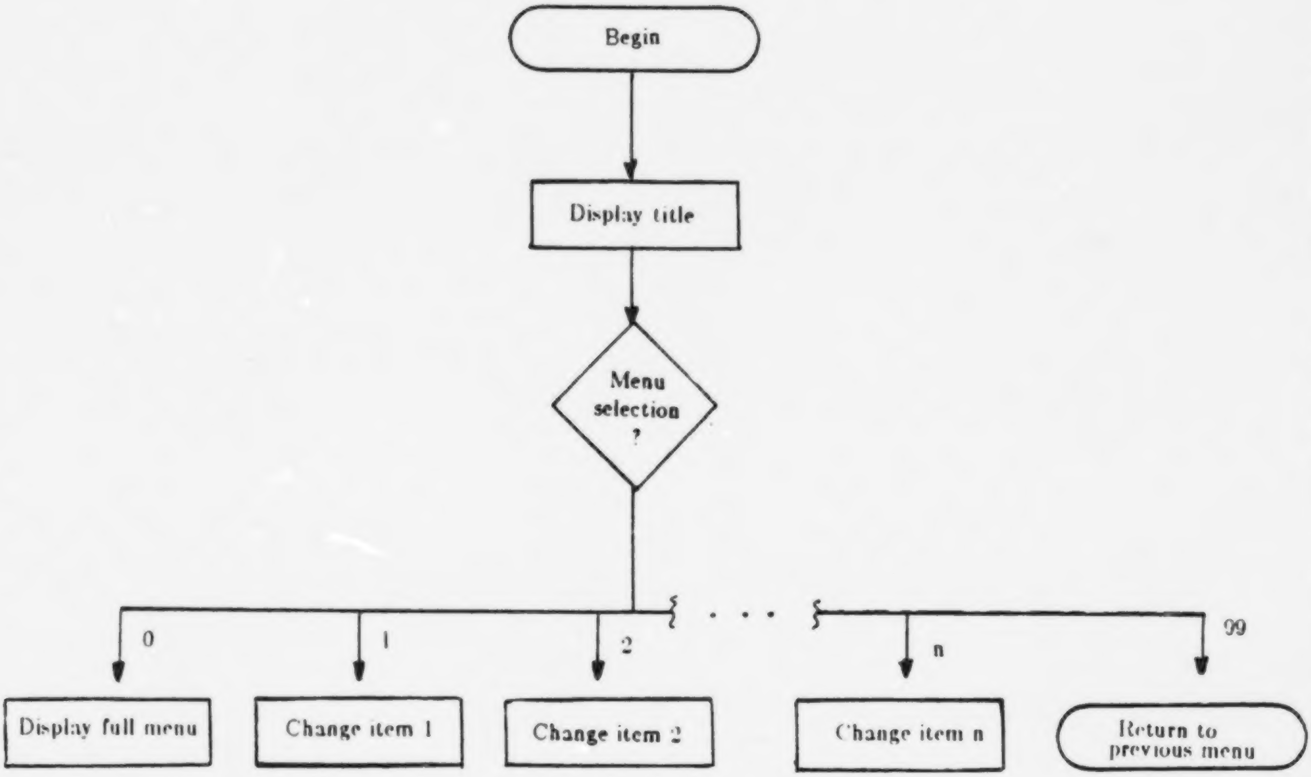


Table D10-1

E8 SCENARIO PARAMETERS AND MODIFYING ROUTINE

Index	Content	Subroutine
-	Title; date	GENRL
1-51	Number of states; state list	GENRL
52,53	Initial year; length of simulation	GENRL
-	Notes	GENRL
54-57	Economic	GFINCE
61-65	Capacity planning	GPLAN
66-70	Operation of model	GMODES
71-80	Pollution control options	GPOLLS
81-86	Economic growth indicators	GROWTH
91-96	Fuel price indicators	GFUEL
101-105 106	Exogenous demand and recalibration End year for coal contracts	GMODES
501-504 510-513	Control technology	STECH
528-530	Emission cost/constraints	SEMISS
540-541	TDP market management	STDP
560-564	Capacity planning data	SPLAN
DG 31	(R)NSPS standards	SRNSPS
DG 26	Target build mix by technologies	SBUILD
YRS17 DG 17	Expected growth rates for demand	SDEMAND
DG17	Net interstate transfer of power	STRNPW
DG 19	Actual levels of demand (recalibration)	SRECAL

10.2.4 Subroutine E8OUT

Called by: SCNGEN

Calls: GETSTA

Task: Writes out new E8 scenario file to I/O unit reference 11.

10.2.5 Subroutine FIPS

Called by: GENRL, STATE

Task: Lists all state names with FIPS codes.

10.2.6 Subroutine FIPSCK

Called by: GENRL, STATE

Arguments: ICOUNT - (input) number of FIPS codes in list to be checked

LIST - (input) list of FIPS numbers

OK - (output) logical result.

Task: Checks numbers in LIST for valid FIPS values. OK set .TRUE. if all are valid.

10.2.7 Subroutine GENRL

Called by: GLOBAL

Calls: ENDFLE, FIPS, FIPSCK, JUDGE, SORT

Task: Modifies general parameters: title, date, states in scenario, years, and notes.

10.2.8 Function GETVAL

Called by: All routines

Argument: VAL - current value displayed at terminal.

Task: Displays current value and reads next value. Null input sets NOVAL switch.

10.2.9 Subroutine GETSTA

Called by: E8OUT, STATE

Arguments: IFIPS - (input) valid FIPS number

NAME - (output) integer array of length four holds 16 character state name.

Task: Converts FIPS number to state name.

10.2.10 Subroutine GFINCE

Called by: GLOBAL

Calls: ENDFLE, GETVAL, JUDGE

Task: Modifies inflation rate, interest (new debt), and desired preferred and common equity returns.

10.2.11 Subroutine GFUEL

Called by: GLOBAL

Calls: ENDFLE, GETVAL, JUDGE

Task: Modifies fuel price growth rates, fuel price indicator, years for non-base scenario and constant fuel prices.

10.2.12 Subroutine GLOBAL

Called by: SCNGEN

Calls: ENDFLE, GCOSTS, GECON, GENRL, GFUEL, GMODES, GPOLLS, GROWTH, JUDGE

Task: Controls all global parameter processing and selection.

10.2.13 Subroutine GMODES

Called by: GLOBAL

Calls: ENDFLE, GETVAL, JUDGE

Task: Modifies switches that control operation of model: dispatching method, coal data, capacity planning, and demand settings.

10.2.14 Subroutine GPLAN

Called by: GLOBAL

Calls: ENDFLE, GETVAL, JUDGE

Task: Modifies global construction cost escalation rates, deferral fraction, deferral dates.

10.2.15 Subroutine GPOLLS

Called by: GLOBAL

Calls: ENDFLE, GETVAL, JUDGE

Task: Modifies pollution control strategies: limited SO_2 compliance options and compliance periods, years dry FGD and LIMB become available, and the TDP market switch and year.

10.2.16 **Subroutine GROWTH**

Called by: GLOBAL

Calls: ENDFLE, GETVAL, JUDGE

Task: Modifies economic growth parameters: personal income, population, earnings growth rates over base, year to begin non-base economic scenario, and year to begin holding economic inputs constant.

10.2.17 **Subroutine INDEX**

Called by: STATE

Arguments: NSTASB - (input) integer number of states in a subset for modification

LSTASB - (input/output) integer array on input contains FIPS codes; on output contains ordinal position of the FIPS code in the state list for the scenario

BAD - (output) logical .FALSE. if a state FIPS in LSTASB is not in the list of states for the scenario

Task: Checks that all states in a modification list are in the scenario and sets up an index to those states

10.2.18 **Subroutine JUDGE**

Called by: All routines

Arguments: VALUE - (input) real value to be judged

IHIGH - (input) integer upper bound on VALUE

LOW - (input) integer lower bound on VALUE

OK - (output) logical .TRUE. if VALUE is within the bounds

Task: Judge numeric responses

10.2.19 Subroutine JUDGEE

Called by: SDPTCH, SEMISS, STDP

Arguments: VALUE - (input) real value to be judged

HIGH - (input) real upper bound on VALUE

XLOW - (input) real lower bound on VALUE

OK - (output) logical .TRUE. if VALUE is within the bounds

Task: Judges real values with large absolute magnitudes for bounds

10.2.20 Subroutine NSTRCT

Called by: SCNGEN

Task: Provides instructions as requested

10.2.21 Subroutine SBUILD

Called by: STATE

Calls: ENDFLE, GETVAL, JUDGE

Arguments: NSTASB - integer number of states in subset of states for modification

LSTASB - integer array of ordinal positions of subset of states in list of states in scenario

Task: Modifies planning target build mix by technology code

10.2.22 Program SCNGEN

Calls: ENDFLE, E8IN, E8OUT, GLOBAL, JUDGE, NSTRCT, STATE

Task: Simple driver program; calls routines in succession to provide instructions, read in a default E8 scenario file, control main selection tasks, and write out new E8 scenario file.

10.2.23 Subroutine SDEMND

Called by: STATE

Calls: ENDFLE, GETVAL, JUDGE

Arguments: NSTASB - integer number of states in subset of states for modification

LSTASB - integer array of ordinal positions of subset of states in list of states in scenario

Task: Modifies expected growth rates for exogenous demand: end years and rates

10.2.24 Subroutine SEMISS

Called by: STATE

Calls: ENDFLE, GETVAL, JUDGE, JUDGEE

Arguments: NSTASB - integer number of states in subset of states for modification

LSTASB - integer array of ordinal positions of subset of states in list of states in scenario

Task: Modifies cost/emission limits for dispatching

10.2.25 Subroutine SORT

Called by: GENRL, STATE

Arguments: NSTATE - (input) number of state FIPS numbers in list

LIST - (input/output) array of FIPS numbers to be sorted

OK - (output) logical .TRUE. if no duplicates in LIST

10.2.26 Subroutine SPLAN

Called by: STATE

Calls: ENDFLE, GETVAL, JUDGE

Arguments: NSTASB - integer number of states in subset of states for modification

LSTASB - integer array of ordinal positions of subset of states in list of states in scenario

Task: **Modifies construction parameters: coal, light water reactor, and oil to coal conversion construction costs; nuclear moratorium year and fraction.**

10.2.27 Subroutine SRECAL

Called by: STATE

Calls ENDFLE, GETVAL, JUDGE

Arguments: NSTASB - **integer number of states in subset of states for modification**

LSTASB - **integer array or ordinal positions of subset of of states in list of states in scenario**

Task: Modifies recalibration years and levels of total sales

10.2.28 Subroutine SRNSPS

Called by: STATE

Calls: ENDFLE, GETVAL, JUDGE

Arguments: NSTASB - **integer number of states in subset of states for modification**

LSTASB - **integer array or ordinal positions of subset of states in list of states in scenario**

Task: Modifies (R)NSPS standards for new units

10.2.29 Subroutine STATE

Called by: SCNGEN

Calls: ENDFLE, FIPS, FIPSCK, GETSTA, INDEX, JUDGE, SBUILD, SCOSTS, SDEMND, SDPTCH, SORT, SRECAL, SRNSPS, STDP, STECH, STRNPW

Task: Controls all state parameter processing and selection

10.2.30 **Subroutine STDP**

Called by: STATE

Calls: ENDFLE, GETVAL, JUDGE, JUDGEE

Arguments:

NSTASB - integer number of states in subset of states for modification

LSTASB - Integer array of ordinal positions of subset of states in list of states in scenario

Task: Modifies TDP market management parameters

10.2.31 **Subroutine STECH**

Called by: STATE

Calls: ENDFLE, GETVAL, JUDGE

Arguments:

NSTASB - integer number of states in subset of states for modification

LSTASB - integer array of ordinal positions of subset of states in list of states in scenario

Tasks: Modifies pollution control technology parameters: land cost, reagent costs, sulfur RSD

Tasks: Modifies pollution control technology parameters: land cost, reagent costs, sulfur RSD exemptions and averaging times

10.2.32 Subroutine STRNPW

Called by: STATE

Calls: ENDFLE, JUDGE

Arguments: NSTASB - integer number of states in subset of states for modification

LSTASB - integer array of ordinal positions of subset of states in list of states in scenario

Tasks: Modifies both quantities and costs of net interstate transfers of power.

10.3 Variables

Major SCNGEN variables and arguments are summarized in Table D10-2.

REFERENCES

1. Caroline J. Badger and Howard Ojalvo. **"Advanced Utility Simulation Model, Documentation of System Design, State Level Model (Version 1.0)."** U.S. Environmental Protection Agency. EPA-600/8-88-071c (NTIS PB89-101208). August 1988.

Table D10-2

VARIABLE INFORMATION FOR SCNGEN

Variable	Location	Size	Units	Description	Accessed by
BAD		1	logical	Indicates illegal FIPS number	INDEX,STATE
CHOICE		1	-	User response to menu list	GENRL,SBUILD, SRNSPS,STATE
ENDSIM	/E8/	1	year	Last year of simulation	E8IN,GENRL,GFUEL, GMODES,GPLAN,GPOLLS, GROWTH,SDEMND,SRECAL
FIRST		1	logical	Indicates first call of routine	All routines
GLOBE	/E8/	75	-	Holds global parameters 54-106	E8IN,E8OUT,STRNPW all global routines
HIGH		1	-	Upper bound for large real numbers	JUDGEE
ICOUNT		1	-	Number of FIPS in list of such	FIPSCK
IDATE	/E8/	2	hollerith	Date of scenario run	E8IN,E8OUT,GENRL,
IDS	/E8/	40	-	Report ID numbers	E8IN,E8OUT,GENRL
IDSUBS	/E8/	40	-	Report index numbers	E8IN,E8OUT,GENRL
IFIPS		1	fips #	FIPS number to get state name	E8OUT,GETSTA
IHIGH		1	-	Upper bound for range tests	ENDFLE,JUDGE
IRTITL	/E8/	40,16	hollerith	Report titles	E8IN,E8OUT
ISELCT		1	-	User response to menu list	All modifying routines
ISTATE	/E8/	1	-	Number of state parameters	E8IN,E8OUT,GENRL
ITITL	/E8/	20,2	hollerith	Scenario title	E8IN,E8OUT,GENRL
IYEAR	/E8/	1	year	Initial year of simulation	E8IN,E8OUT,GENRL
LIST		48	fips #	List of FIPS numbers	FIPSCK,GENRL,SORT
LOW	-	1	-	Lower bound for range tests	ENDFLE,JUDGE

Table D10-2 (contd.)

Variable	Location	Size	Units	Description	Accessed by
LSTASB		48	-	Ordinal position in scenario state list of subset of states for modification	INDEX, all state routines
LSTATE	/E8/	50		List of states in scenario	E8IN, E8OUT, GENRL, INDEX, SDEMND, all state routines
NAME		4	hollerith	16 character state name	GETSTA
NDG17	/E8/	1	-	Number of periods in dg 17	E8IN, E8OUT, SDEMND
NDG19	/E8/	1	-	Number of sectors in dg 19	E8IN, E8OUT
NGLOBE	/E8/	1	-	Number of global parameters	E8IN, E8OUT
NNOTE	/E8/	1	-	Number of note lines	E8IN, E8OUT, GENRL
NOTES	/E8/	20,23	hollerith	Write 20 lines of 92 character notes	E8IN, E8OUT, GENRL
NOVAL	/E8/	1	logical	Indicates no new value for an item	GETVAL, all modifying routines
NREPTS	/E8/	1	-	Number of reports	E8IN, E8OUT, GENRL
NRNSPS	/E8/	1	-	Number of (R)NSPS parameters	E8IN, E8OUT, GENRL, SRNSPS
NSORT		1	-	Number of states to be sorted	SORT
NSTASB		1	-	Number of states in sub-set to be modified	INDEX, all state routines
NSTATE	/E8/	1	-	Number of states in scenario	E8IN, E8OUT, GENRL, INDEX, STATE
NTECH	/E8/	1	-	Number of plant technologies	E8IN, E8OUT, GENRL, SBUILD
NYEAR	/E8/	1	-	Number of years in simulation	E8IN, E8OUT, GENRL, STRNEW
OK		1	logical	Result of range test of user menu choice	JUDGE, JUDGEE, all routines

Table D10-2 (contd.)

Variable	Location	Size	Units	Description	Accessed by
PEXDEM	/E8/	48,5,4	% growth	Exogenous demand growth rates	E8IN, E8OUT, GENRL, SDEMND
PEXEND	/E8/	48,5	years	End years for exogenous demand growth	E8IN, E8OUT, GENRL, SDEMND
PLVDEM	/E8/	48,4	dollars	Levels of demand, recalibration	E8IN, E8OUT, GENRL, SRECAL
PRNSPS	/E8/	48,50	-	(R)NSPS standards, years	E8IN, E8OUT, GENRL, SRNSPS
PSTATE	/E8/	48,75	-	Holds state parameters 500-564	E8IN, E8OUT, GENRL, SEMISS, SPLAN, STECH
PTECH	/E8/	48,30	fractions	Building mix by technologies	E8IN, E8OUT, GENRL, SBUILD
STANAM		4	hollerith	16 character state name	E8OUT, STATE
VAL		1	-	Current value of an item	GETVAL
VALUE		1	-	Value judged for range	JUDGE, JUDGEE
WORKVR		1	-	New value from user input	all modifying routines
XLOW		1	-	Lower bound for small real numbers	JUDGEE

D11. THE REPORT SELECTOR

by
Howard Ojalvo

Universities Research Group on Energy
University of Illinois at Urbana-Champaign

11.1 Overview

There are four distinct phases in the process of generating reports from the Advanced Utility Simulation Model (AUSM): (1) dumping raw data from AUSM, (2) sorting the dump file, (3) specifying report options and (4) writing reports. Figure D11-1 depicts the general flow of this process. Phases 1, 2 and 4 are discussed in Chapter C9. This chapter discusses the third phase, specification of report options.

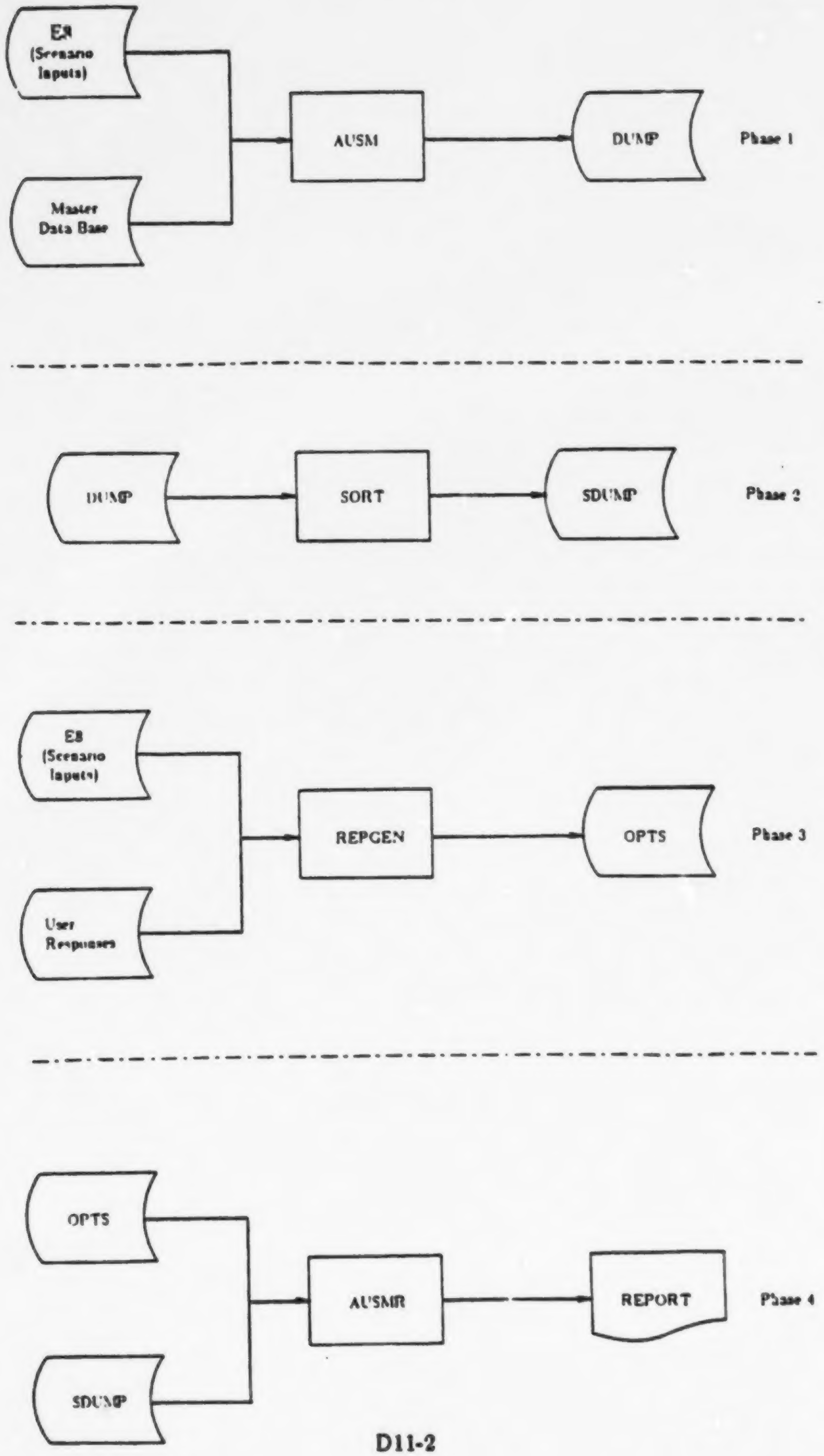
REPGEN is an interactive program for the selection of reports to be generated, the reporting years for each report selected and the states for which each report is to be generated. REPGEN reads the following information from the AUSM scenario file:

Scenario title,
Date on which AUSM was run,
Number of states in scenario and state list, and
First year of simulation and length of simulation.

REPGEN combines the user-selected options with scenario specific information to create a single option file, OPTS, which is input to the report writing program, AUSMR.

REPGEN is an interactive program for selecting AUSM reports for generation as well as for specifying year and state parameters for the reports selected. REPGEN thus inputs a range of years and a list of states for a specific AUSM run from file E8, the scenario file, and queries the user as to which states and years to include in each report subsequently generated by AUSMR. Selections are communicated to AUSMR via the output file OPTS.

Figure D11-1
AUSM REPORT GENERATION PHASES



The overall control flow of REPGEN is reflected in the main program, which, in succession, calls routines to select reports for generation (SELREP), to specify year and state options (SELOPT), to modify any selections made (MODREP), and, finally, to write specifications to the output file (WROPTS).

11.2 Subprogram Summaries

Table D11-1 provides brief synopses of REPGEN subprograms. These subprograms are summarized in Sections 11.2.1 through 11.2.19.

11.2.1 Function ICKSTA

Called by:	ISOPTN.
Argument:	ISTATE - FIPS state code.
Task:	Integer function; returns the value '1' if ISTATE is a valid FIPS state code. Otherwise, '0' is returned.

11.2.2 Function ICKYER

Called by:	IYSPTN.
Argument:	IYEAR.
Task:	Integer function; returns the value '1' if IYEAR is within the range of years specified in the AUSM scenario. Otherwise, '0' is returned.

11.2.3 Subroutine INIT

Called by:	REPGEN.
Tasks:	Reads scenario input from the SCNDIR file to:

Table D11-1
SYNOPSES OF REPGEN SUBPROGRAMS

Subprogram	Synopsis	Called by
ICKSTA	Integer function; tests validity of FIPS state code	ISOPTN
ICKYER	Integer function; tests validity of year input	IYOPTN
INIT	Begins user session by rewinding files and reading and testing validity of scenario input file	REPGEN
INTRO	Prints REPGEN scenario banner consisting of title, date run, etc.; provides user instructions if needed	REPGEN
IOPUT	Coordinates user data inputI	SOPTN, IYOPTN MODREP, SELREP
ISOPTN	Reads user state option lists	SELOPT
IYNREP	Returns user response to a yes/no question	INTRO, ISOPTN, MODREP, SELOPT, SELREP
IYOPTN	Reads year selections	SELOPT
LISTIO	Reads free-formatted user input	IOPUT
MKZERO	Zero-fills an array	IOPUT, ISOPTN, IYOPTN, MODREP, SELREP
MODREP	Coordinates user modifications of reports already specified	REPGEN
NUMYER	Translates years from Julian form to a two-digit index	IYOPTN
REPGEN	Main program; coordinates selection of options	
REPLST	Prints list of report identifiers	MODREP, SELREP
REVIEW	Prints report description	MODREP, SELREP
SELOPT	Routine for selecting state and year	MODREP, REPGEN

	options for a specific report	
SELREP	Routine for selecting reports	REPGEN
SORT	Sorting utility routine	IOPUT, ISOPTN, IYOPTN, MODREP
WROPT	Writes user options to OPTS file	REPGEN

1. Echo data to OPTS file.
2. Load REPGEN scenario variables.
3. Check validity of data read in.

11.2.4 Subroutine INTRO

Called by: REPGEN.

Task: Prints program banner consisting of title, date run, etc., and user instruction if requested.

11.2.5 Subroutine IOPUT

Calls: LISTIO, MKZERO, SORT.

Arguments: NROWS - Row dimension of IARRAY.

NCOLS - Column dimension of IARRAY.

IARRAY - Buffer to which validated data are written.

LINE - Row of IARRAY to which data are written.

KOUNT - Number of data elements read.

Task: Coordinates user input of lists.

Method: Calls LISTIO to read a free formatted list of numbers. The list is then tested for duplicates and sorted in ascending order. Data are put in IARRAY.

11.2.6 Subroutine ISOPTN

Called by: SELOPT.

Calls: ICKSTA, IOPUT, IYNREP, MKZERO, SORT.

Arguments:

NROWS - Row dimension of IARRAY.

NCOLS - Column dimension of IARRAY.

IARRAY - Working array for storage of user-specified options.

LINE - Row of IARRAY to which state data are written.

KOUNT - Number of states read.

NSTATE - Number of states in current scenario.

ISTA - List of FIPS state codes included in current scenario.

ISTABB - List of state abbreviations.

Task: Inputs a list of states selected by the user.

Method: User is given the option to include all states or to select states individually. In the latter case, help is given if needed. Input data are verified.

11.2.7 Function IYNREP

Called by: INTRO, ISOPTN, IYOPTN, MODREP, SELOPT, SELREP.

Task: Integer function; reads and interprets a user response to a yes/no question. IYNREP returns the following values:

1 in response to the letter 'N' (no)

2 in response to the letter 'Y' (yes)

3 in response to the letter 'H' (help)

The user is continually prompted until a valid response is obtained.

11.2.8 Subroutine IYOPTN

Called by: SELOPT.

Calls: IOPUT, IYNREP, MKZERO, NUMYER, SORT.

Arguments:

NROWS - Row dimension of IARRAY.

NCOLS - Column dimension of IARRAY.

IARRAY - Working array for storage of user-specified options.

LINE - Row of IARRAY to which data are written.

KOUNT - Number of years read.

NYEARS - Number of years in AUSM scenario.

IYEAR1 - First year of simulation.

IENDYR - Last year of simulation.

Task: Prompts the user to specify years to be included in a specific report. The user may optionally specify all years, individual years, or a beginning year and a yearly increment.

11.2.9 Subroutine LISTIO

Called by: IOPUT.

Arguments: IVAL - Array of integer numbers input by user.

Task: Reads free formatted integer lists.

Method: Reads the list of numbers input by user in A-format. This list is written to a scratch file and read back, using a list-directed read, to the IVAL array.

11.2.10 Subroutine MKZERO

Called by: IOPUT, ISOPTN, IYOPTN, MODREP, SELREP.

Arguments:

NROWS - Row dimension of IARRAY.

NCOLS - Column dimension of IARRAY.

IARRAY - Working array for storage of user-specified options.

LINE1 - Beginning line to be zero-filled in IARRAY.

LINE2 - Last line to be zero-filled in IARRAY.

Task: Zero fills LINE1 to LINE2 of IARRAY.

11.2.11 Subroutine MODREP

Called by: IOPUT, IYNREP, MKZERO, REFLST, REVIEW, SELOPT, SORT.

Arguments:

NROWS - Row dimension of IARRAY.

NCOLS - Column dimension of IARRAY.

IARRAY - Working array for storage of user-specified options.

IKNOUNT - Number of reports added or modified by INODREP.

IRNUMB - List of report identifiers.

IRDESC - Report descriptions.

Task: Permits the user to modify any report selection previously made or to add new reports.

Method: User may optionally view selections already made as well as the complete list of reports. He or she may then enter the identifier numbers of the reports to be modified or added. Subroutine SELOPT is called to effect these changes and additions.

11.2.12 Subroutine NUMYER

Called by: IYOPTN.

Arguments: NROWS - Row dimension of IARRAY.

NCOLS - Column dimension of IARRAY.

IARRAY - Working array for storage of user-specified options.

LINE - Row of IARRAY to which year data are written.

KOUNT - Number of years to be converted.

IYEAR1 - First year of simulation.

Function: Translates years from Julian form to a two-digit index.

11.2.13 Program REPGEN

Calls: INIT, INTRO, MODREP, REVIEW, SELOPT, SELREP, WROPTS.

Task: Simple driver program; calls routines in succession to select reports and options, to review and modify selections, and finally to write user-selected options to the OPTS file.

11.2.14 Subroutine REPLST

Called by: MODREP, SELREP.

Task: Prints list of report identifiers. Reports already selected are flagged with an asterisk.

11.2.15 Subroutine REVIEW

Called by: MODREP, SELOPT.

Argument: NUMBER - Index of a selected report.

Task: Prints description of a selected report.

11.2.16 Subroutine SELOPT

Called by: MODREP, REPGEN.

Calls: ISOPTN, IYNREP, IYOPTN, REVIEW.

Arguments:

NROW - Row dimension of IARRAY.

NCOL - Column dimension of IARRAY.

IARRAY - Working array for storage of user-specified options.

KOUNT - Number of reports selected.

IRNUMB - List of report identifiers.

IRDESC - List of report descriptions.

IMOD - Parameter = 1 if routine called for initial option selection;

= 2 if called to make modifications to options.

Task: Supervises selection of state and year options for a specified report.

11.2.17 Subroutine SELREP

Called by: REPGEN.

Calls: IOPUT, IYNREP, MKZERO, REPLST.

Arguments:

NROW - Row dimension of IARRAY.

NCOL - Column dimension of IARRAY.

IARRAY - Working array for storage of user-specified options.

KOUNT - Number of reports selected.

NREPTS - Number of reports in AUSM scenario.

IRNUMB - List of report identifiers.

Task: Permits user to specify list of reports; user may optionally select all reports.

11.2.18 Subroutine SORT

Called by: IOPUT, ISOPTN, IYOPTN, MODREP.

Arguments:

NROWS - Row dimension of IARRAY.

NCOL - Column dimension of IARRAY.

IARRAY - Working array for storage of user-specified options.

LINE - Row of IARRAY to sort.

	KOUNT - Number of elements in LINE to sort.
Task:	Sorts a single row in IARRAY by the bubble sort method.

11.2.19 Subroutine WROPTS

Called by:	REPGEN.
Task:	Writes user-selected reporting options from the IOPLIN storage array to the OPTS output file.